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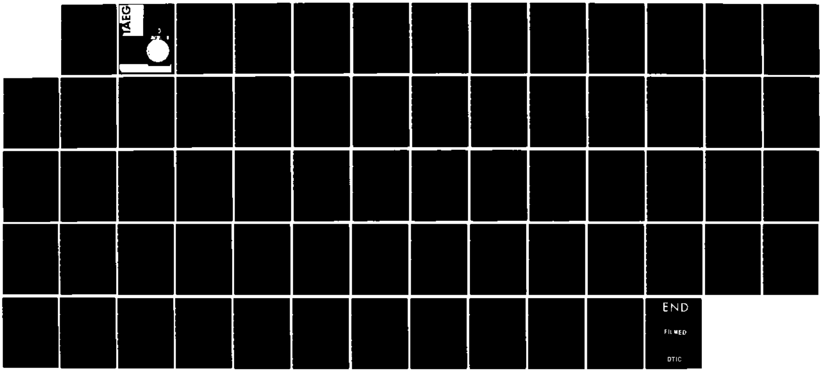

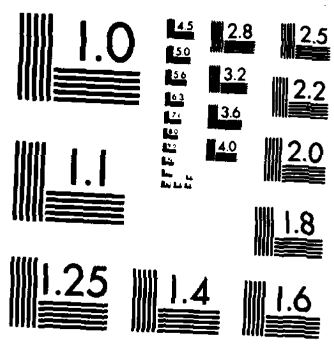
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TECHNICAL REPORT NO. 105

ECONOMIC ANALYSIS OF INDIVIDUALIZED AND CONVENTIONAL INSTRUCTION

JUNE 1981

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TRAINING ANALYSIS AND EVALUATION GROUP
ORLANDO, FLORIDA 32813

TAEG Report No. 105

ECONOMIC ANALYSIS OF INDIVIDUALIZED AND CONVENTIONAL INSTRUCTION

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Training Analysis and Evaluation Group

June 1981

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents a cost-effectiveness analysis of computer managed instruction, instructor managed instruction, and conventional instruction.

A life-cycle costing approach was applied to the Radioman-A Core and the Interior Communications Electrician-A courses using the individualized and conventional strategies.

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20. ABSTRACT (continued)

The analysis included:

- a review of all the factors that make up the life-cycle costs of a course,
- an application of the life-cycle costing approach to evaluate conventional instruction and individualized instruction,
- sensitivity analyses to learn how changes in certain factors affect the costs of those strategies.

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SECTION I

INTRODUCTION

During recent years, there has been an increasing trend toward the individualized instruction (II) strategy in place of the conventional instruction (CI) strategy. Many questions and concerns have been raised concerning the relative effectiveness and efficiency of the two competing strategies (Zajkowski, Heidt, Corey, Mew, and Micheli, 1979; Orlansky and String, 1979).

One concern is the total absence of a complete cost-effectiveness analysis comparing the CI and II strategies (Orlansky and String, 1979, pp. 3, 6-7). Such a managerial analysis is crucial. If one accepts the premise that both strategies have the capability of training students to reach a given level of proficiency, then the only acceptable criteria for strategy selection should be life-cycle costs, with the lowest cost alternative being implemented.

OBJECTIVE

The objective of this study is to perform a cost-effectiveness analysis of II and CI. This analysis will include: (1) a review of all the factors that make up the life-cycle costs of a course, (2) an application of the life-cycle costing approach to evaluate CI and II strategies for two actual courses, and (3) sensitivity analyses to learn how changes in certain factors affect the costs of those strategies.

No attempt will be made to evaluate the relative effectiveness of II vs. CI. Such an evaluation must await the collection of more training effectiveness data. This report is premised upon the assumption that both strategies are equally effective, and, therefore, any decision involving their selection should be based on dollar costs alone.

DEFINITIONS

Much of the terminology related to II does not have universally accepted definitions. Therefore, to avoid confusion, the following definitions will be used:

Individualized Instruction (II). An instructional strategy in which all learning activities are designed to accommodate individual differences in background, skill level, aptitude, and cognitive style. Individualized instruction is characterized by the following attributes:

- releasing of time constraints
- choice of instructional media
- instruction adjusted to skill levels and learner characteristics. It often employs programmed instruction.

Conventional Instruction (CI). An instructional strategy in which learning activities are directed toward a normative model of the target

population characteristics and usually delivered in a group environment. It is characterized by:

- predetermined group pacing
- preselected nonvariant media
- predetermined nonvariant instruction.

These characteristics, once established, are employed with all members of the group.

Computer Managed Instruction (CMI). An instructional management system in which a computer is employed to prescribe a series of instructional materials for individual trainees. Usually associated with II, it may include the capability for record keeping, testing, counseling, and selecting various media for the delivery of instruction.

Instructor Managed Instruction (IMI). An instructional management system in which the instructor prescribes a series of instructional materials for individual trainees. It is usually associated with the delivery of II and may include the capability for record keeping, testing, counseling, and selecting various media for the delivery of instruction.

Instructional Systems Development (ISD). A systematic process (framework) for applying approved procedures and techniques in developing and conducting training. This process usually includes five phases: analyze, design, develop, implement, and control.

SCOPE OF THE REPORT

COST-EFFECTIVENESS VS. COST-BENEFIT ANALYSIS. A cost-effectiveness analysis compares the costs of several alternative courses of action which perform equally well. This is the approach used in this report. The alternative course configurations being evaluated are assumed to train these students equally well; i.e., endow them with the same set of skills required to perform a given set of tasks.

A cost-benefit analysis compares several alternatives which might perform with varying degrees of effectiveness. This more complex evaluation is not the subject of this report. Although some people claim that II programs will always train Navy technicians more effectively than CI, and other people claim the opposite, there exists no convincing evidence to support either position. In the absence of such evidence, the most useful information for managers and planners can be derived from the cost-effectiveness analytical approach.

LIMITED II ALTERNATIVES. In its purest form, II would offer students (1) self-pacing and (2) a choice of several diverse media throughout the course. The II alternatives evaluated in this study are based upon the Radioman (RM)-A and Interior Communications Electrician (IC)-A courses as they are currently being taught within the Navy. The courses satisfy the self-pacing criteria

for individualized courses, but fall short in the selection of media offered the students. In some modules students may choose from sound-slide, programmed text, and narratives. However, more often they are offered one or two of these media. Consequently, the reader must bear in mind that although the courses analyzed in this study represent an extensive application of some individualized training concepts within the Navy's technical training program, they may not be as fully individualized as proponents of II feel they should be.

ORGANIZATION OF THE REPORT

In addition to this section, the report contains three sections and three appendices. Section II provides the theoretical background for the life-cycle costing approach in decision making. In section III the life-cycle costing approach is applied to the RM-A Core and the IC-A courses with both the individualized and conventional strategies. Section IV presents the conclusions and recommendations of this analysis. Appendix A reviews the mechanics of discounting; appendix B includes financial pro forma statements; appendix C outlines the model used to determine the effect of student loading upon RM-A Core and IC-A life-cycle costs.

SECTION II

COST THEORY

LIFE-CYCLE COSTS

The question being considered here is which method of production will produce a certain, specified output at least cost. The method used to answer the question is to (1) carefully formulate the alternatives in order to determine the resources needed to perform them and (2) estimate the costs of these resources. That alternative which produces the given output at least cost is the most efficient.

The "output" in this cost application is a certain number of graduates per year who are trained to some specified level, and the "alternative methods of production" are the CI and II strategies of training.

RELEVANT VS. IRRELEVANT COSTS. Once the alternatives have been well specified, the only costs that need be estimated in order to show relative efficiency are the relevant costs. Relevant costs are those costs which exhibit the characteristics of futurity and variability. Futurity means that the costs being considered will be incurred in future time periods; i.e., are not yet "sunk." For example, if a school were using a computer which was purchased new for $4,000 10 years ago, and which is worth only $1,500 today, it should be costed in today's analysis at $1,500. The $4,000 purchase price is an irrelevant historical datum, or a "sunk" cost.

Variability means that the costs differ across the alternatives. For example, student costs and instructor costs vary across the alternatives because the average-on-board (AOB) strengths are different. Consequently, they are relevant to this study. Conversely, such overhead costs as Service School Command management and most Chief of Naval Education and Training/Chief of Naval Technical Training (CNET/CNTECHTRA) support are the same in all the alternatives and are, therefore, irrelevant and not included. In this study, most of the costs incurred in the schoolhouse were considered relevant, while most others were judged irrelevant.

TIMING OF COSTS. Two dimensions must be considered in any cost analysis--the absolute amount of the cost and the time in which the cost will be incurred. Given the choice between giving up one dollar today or a year from today, the rational person would choose to hold it and surrender it a year from today. The reason is that the person who holds that dollar could invest it in real productive resources (or loan it to someone else to invest in real resources) and earn a real return on it. Therefore, a dollar today is worth more than a dollar tomorrow; the degree to which it is worth more depends on the value of commercial investments. Department of Defense (DOD) research indicates that 10 percent per annum is the appropriate discount figure to use in estimating how much less valuable future dollars are when compared to present day dollars.

Consequently, the lifetime cost of any one system cannot be estimated by simply summing the annual costs over the life of the system. The mixing of less valuable future dollars with more valuable current dollars would be

ppropriate. Analysts typically use the present year's dollar as a standard, ust the future annual costs downward by 10 percent per annum, and then sum annual (discounted) dollars to obtain the total costs as measured in sent dollars, or the life-cycle costs. (Appendix A exemplifies this cess for the interested reader.)

Inflation--defined as a rise in all prices--has no affect on the present ue life-cycle costing procedure. The 10 percent discount rate directed DOD use is predicated upon the assumption that uninflated, constant lars will be used throughout the analysis. Technically, one has the ion of using inflated dollars in the analysis. However, the appropriate count rate would then be the real rate (10 percent) plus the inflation e, and the solution would be the same as described in the preceding para- ph. Only in the case where price increases occur at different rates among cost categories does the analyst need to be concerned with inflationary ce changes. (Such an instance will be addressed in this report in the sitivity analyses where active duty compensation is allowed to increase e rapidly than the general price level.)

MARY. The appropriate cost estimate to use when comparing one system with ther is the life-cycle cost. It is calculated by summing the discounted ual costs throughout the life of the system. Assuming that the alternative tems produce the same quality and quantity of output, the system with the est life-cycle cost should be preferred to those with higher life-cycle ts.

TEM COST BEHAVIOR

Most systems exhibit similar patterns of cost behavior over time. One ical pattern is that which describes the relationship between research and elopment (R&D), investment, and operating costs (see figure 1).

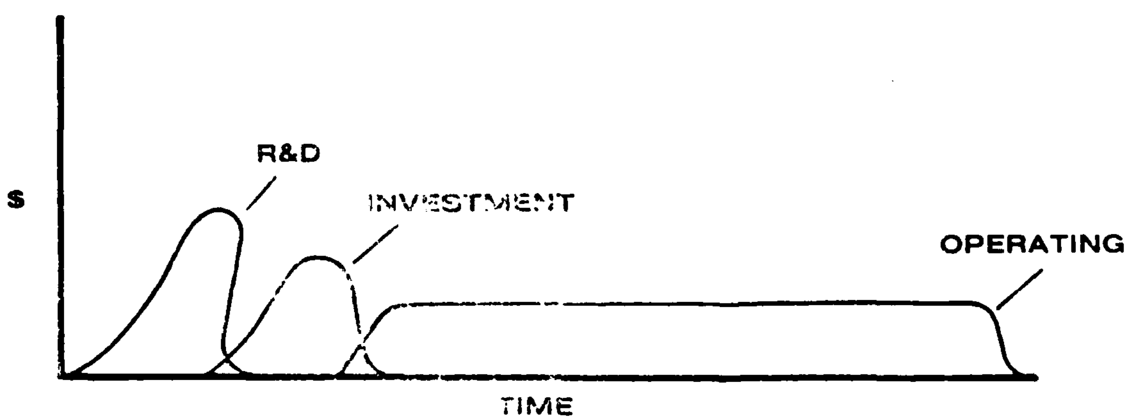


Figure 1. Typical Life-Cycle Cost Profile

Maintenance and [illegible] activities. The $4.75/ft² factor for annual maintenance [illegible] the classes (page 17) was used for the CI estimate. [illegible] annual costs would total $162,000.

Curriculum Maintenance. [illegible] active, actions would be required to keep the curri[illegible] the life of the course. This cost was assumed to be [illegible] course development costs. In the real life CI [illegible] costs are totaling approximately 10 percent of the [illegible] costs. Ten percent times the CI developmental [illegible] annual curriculum maintenance projection of $88,[illegible]

Summary. Total [illegible] for RM-A Core in the CI mode are:

[illegible]	$ 936,000
[illegible]	6,446,000
[illegible]	66,000
[illegible]	
[illegible]	162,000
Curriculum Maintenance	88,000

[illegible] Costs $7,698,000

Life-Cycle Cost [illegible]. Table 4 shows the [illegible] investment costs, annual oper[illegible] life-cycle costs for RM-A Core with the CMI, IMI, and [illegible] costs are discounted; appendix [illegible] provides a pro [illegible] counted budget costs.

SENSITIVITY ANALYSIS. [illegible] assumptions and estimates were made which [illegible] evaluate the potential impacts of these possible [illegible] analysis was performed. The RM-A Core life-cycle [illegible] for scenarios where:

- develop[illegible] resized CI course ranged from 50 percent [illegible] development costs (or $594,000 to 1,188,[illegible]
- course [illegible] the CI course ranged from 100 percent [illegible] course length (or 7.4 weeks to 10 weeks)
- costs [illegible] rose from 0 percent to 10 percent more [illegible]
- the [illegible] training for the CMI system would cost 50 [illegible] 000 originally estimated, or would [illegible] $100,000
- comm[illegible] from $50,000 to $[illegible] per year
- the [illegible] alternatives varied from 0 to [illegible]

jor Equipment. Projected equipment requirements include:

177	UGC-6 teletypewriters
107	TT-47 teletypewriters

fferences between this listing and the CMI listing (page 14) are (1) the
/ious absence of computer equipment, video players, and sound slide sets,
i (2) an increase in teletypewriter requirements.

Even though AOB has been increased by 20 percent, the teletypewriter quirement was raised by only 10 percent. The rationale was that some of e current "lab" RM-A Core sessions are (under CMI) taught in a lock-step shion. Consequently, if the entire course were transformed to group- cing, the intensity of teletypewriter use in these labs would not change. the other hand, other labs do use their machines in a self-paced manner-- one student finishes, he leaves and is replaced by another. If the course re transformed to CI, these machines would be used less intensely, and the nber of machines required would, therefore, rise.

Video players and sound slide sets are not required because the only dia in the hypothesized CI course are written narratives and instructors' ctures.

The total investment cost for equipment is estimated to be $1,208,000. e useful life is assumed to be 15 years.

mmary. Total investment costs for the RM-A Core course in the CI configura- on are:

Curriculum Development	$ 832,000
Class Facilities	1,115,000
Equipment	1,208,000
Total Investment Costs	$3,155,000

erating Costs. Operating costs for RM-A Core in the CI mode include those sts for staff, students, supplies, maintenance/utilities for the school cilities, and curriculum maintenance.

aff Costs. The student-instructor ratio was assumed not to vary with structional strategy. Consequently, the 20 percent increase in student AOB ojected for the CI alternative would cause a 20 percent increase in CI aff costs vis-a-vis CMI staff costs. The resulting cost estimate for staff quirements is $936,000 annually.

udent Costs. Since the rank of the students is constant across the alter- tives, the 20 percent increase in AOB between the II and CI alternatives l cause the CI students' costs to rise by 20 percent; the projected total nual cost for the CI alternative is $6,446,000.

pplies. Supplies for the CI alternative are assumed to be the same as ose for the CMI course, or $66,000 per year.

how did course quality and content differ under the competing strategies. However, overall student time savings averaged approximately 30 percent in favor of II when compared to CI.

In the economics literature, the question of learning rates is being addressed more frequently. Siegfried and Fels (1979) reported that the consensus concerning the teaching of basic economics is that "programmed learning (which is most like Naval II) is efficient in the sense of bringing students to a given level of competence in less time...." Their conclusion was based on a survey of numerous economic studies performed during the 1970's.

Given these items of research, the assumption of a 20 percent increase in course length when going from II to CI appeared realistic. Realizing the controversy revolving about this question, a sensitivity analysis will be performed where course length will be allowed to vary.

Another difference between the II course profiles and the CI profile is the lack of a sophisticated course management system for the latter. In the conventional lock-step system, the students proceed through a common curriculum in unison; management is relatively easily performed by the regular complement of instructors and base military personnel sections.

The components of the life-cycle costs of the RM-A Core course in the CI mode follow:

Investment Costs. These costs include curriculum development, class facilities, and major equipment.

Curriculum Development Costs. Historical data on course development costs within DOD have been described by Orlansky and String (1979) as so "meager" that any generalized predictions based on these data are impossible. The TAEG concurs with their conclusion. Within NAVEDTRACOM, only with the recent beginning of the IPDCs, costs have been collected for course development. Although the accounting has been thorough, the number of courses completed is so small that the data cannot be used to accurately predict the variation between CI and II development costs.

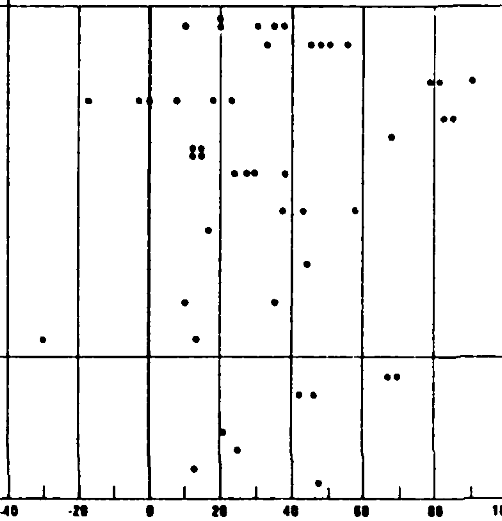
Managerial opinion, both within the Navy and economic education circles, is practically unanimous in the claim that II courses cost more to develop than CI courses. The few dissenting opinions expressed maintain that development costs are not affected by instructional strategy.

For the initial costing of RM-A Core in the CI mode, the "moderate" assumption was made that the development costs are 70 percent of those incurred in the CMI alternative, or $832,000.

Class Facilities. Class requirements are a function of AOB. Since the CI approach would mean 20 percent more students at any given time, it is assumed that 20 percent more class space (vis-a-vis II) is required. When priced at $36 per sq foot and adjusted for life-cycle variations (see page 14), this 34,400 sq feet of space translates to a $1,115,000 investment requirement.

TABLE 3. TIME SAVINGS OF COMPUTER ASSISTED AND COMPUTER MANAGED COURSES OVER CI COURSES*

METHOD OF INSTRUCTION	SYSTEM	SERVICE	LOCATION	STUDENT TIME SAVINGS (compared to conventional instruction)	TYPE OF TRAINING	REFERENCES**
CAI	IBM 1500	A	SIGNAL C&S		ELECTRONICS	IBM (1968), Longo (1969, 1972) Giunti and Longo (1971a&b)
		N	SAN DIEGO		ELECTRICITY	Ford & Slough (1970), Hurlock & Lahey (1971, 1972), Ford, Slough et al (1972)
	PLATO IV	A	ABERDEEN		MACHINIST	U.S. Army Ordnance Center and School (1975)
		N	SAN DIEGO		ELECTRONICS	Stern (1975), Lahey, Crawford et al (1976), Slough and Coady (unpubl.)
		N	SAN DIEGO		RECIPE CONVERSION	Fredericks and Hoover-Rice (1977)
		N	NORTH ISLAND		A/C PANEL OPERATOR	Crawford, Hurlock et al (1976)
		AF	SHEPPARD		MEDICAL ASSISTANT	Steinkerchner, Deignan et al (1977), Deignan and Duncan (1977)
		AF	CHANUTE		VEHICLE REPAIR	Dallman, DeLeo et al (1977)
	LTS-3	AF	KEESLER		ELECTRONICS	Harris, Grossberg et al (1972), Keesler AFB (1972, 1973)
		AF	KEESLER		WEATHER	Downs, Johnson et al (1972)
	TICCIT	N	NORTH ISLAND		TACTICAL CO-ORD. (S-3A)	Walker (1978)
	IDIOM	N	DAM NECK		FIRE CONTROL TECHNICIAN	General Electric Ordnance Systems (1975), Radsken and Grosson (1975)
	PLATO IV	N	DAM NECK		FIRE CONTROL TECHNICIAN	General Electric Ordnance Systems (1975), Radsken and Grosson (1975)
CMI	NAVY CMI	N	MEMPHIS		AVIATION FAMILIARIZATION	Carson, Graham et al (1975)
		N	MEMPHIS		AV. MECH. FUNDAMENTALS	Carson, Graham et al (1975)
	AIS	AF	LOWRY		INVENTORY MGMT.	Briefing (1978)
		AF	LOWRY		MATERIEL FACILITIES	Briefing (1978)
		AF	LOWRY		PREC. MEASURING EQPT.	Briefing (1978)
		AF	LOWRY		WEAPONS MECHANIC	Briefing (1978)



*SOURCE: Orlansky and String, 1979, p. 45
**References are cited on p. 50 of this report.

TABLE 2. RM-A CORE COSTS--CMI AND IMI

	CMI	IMI
INVESTMENT COSTS--Onetime		
Curriculum Development	$1,188,000	$1,188,000
Specialized Programming	20,000	0
Class Facilities	929,000	929,000
Equipment	1,124,000	1,129,000
TOTAL	$3,261,000	$3,246,000
OPERATING COSTS--Annual		
Staff	$ 780,000	$1,048,000
Student	5,860,000	5,860,000
Computer Lease	53,000	0
Facilities Maintenance/Utilities	134,000	134,000
Supplies	66,000	66,000
Curriculum Maintenance	120,000	120,000
TOTAL	$7,013,000	$7,228,000
15 YEAR LIFE-CYCLE COST*	$59,224,000	$60,925,000

*Investment and all operating costs over the expected 15 year life of the course, discounted to present value terms.

Also, to complete the transformation of the CMI costs into IMI costs, the following amounts must be subtracted from CMI costs:

ONETIME INVESTMENT:

Specialized Programming	($20,000)

ANNUAL OPERATING COSTS:

Computer Leasing	($53,000)

Summary. Table 2 shows the total investment costs, annual operating costs, and 15 year life-cycle costs for the CMI and IMI instructional strategies for the RM-A Core course. The life-cycle costs are discounted; appendix B provides a pro forma statement with undiscounted budget costs.

CONVENTIONAL INSTRUCTION CONFIGURATION. A hypothesized RM-A Core course taught with a conventional instruction strategy was the most difficult of the three options--CMI, IMI, and CI--to cost estimate. Current research and managerial opinions are not unanimous as to how resource use changes, and to what degree it changes, when individualized and conventional strategies are compared.

The profile of the CI RM-A course to be costed in this section follows:

- group-paced--8.6 weeks long
- 2,600 graduates annually, predominantly E-1's through E-3's
- media--printed narratives and instructors' lectures
- location--Service School Command, San Diego
- assumed useful life of the curriculum is 15 years.

The differences between the CI profile and the preceding individualized profiles are the increased course length, more limited media, and the lack of an elaborate course management system. The length of the CI version is assumed to be 20 percent longer than the IMI and CMI versions, or 8.6 weeks. This longer course (with equal number of graduates) will drive the AOB higher, which in turn will increase facility, student, staff, and some equipment costs.

The intuitive evidence supporting the assumption of an increased average course completion time for CI when compared to II is very strong. If one accepts the fact that any group of students possesses varying abilities, then it follows that when training them in a lock-step setting some will be learning at a slower pace than they are capable.

Empirical evidence supports this theory. Table 3 from Orlansky and String (1979) summarizes well the studies done within DOD. As the authors point out, serious questions exist concerning some of these studies; e.g.,

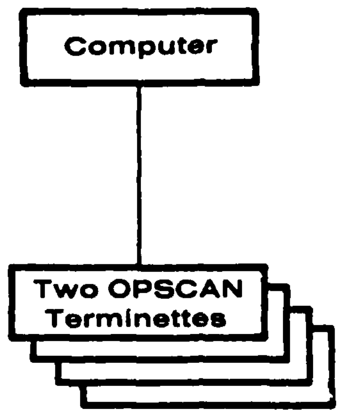


Figure 2. CMI Management System (RM-A Core)

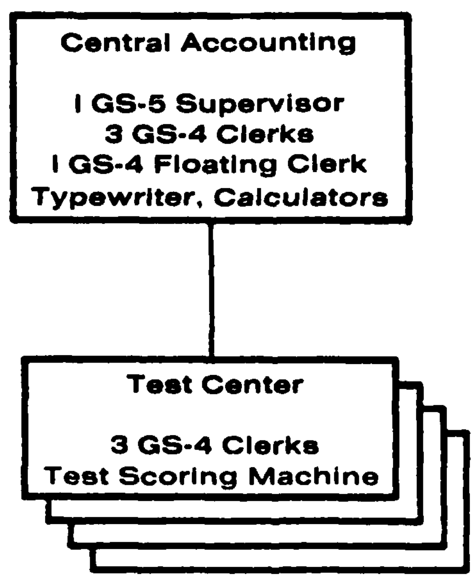


Figure 3. IMI Management System (RM-A Core)

- media--printed, sound slide, video, and lectures
- location--Service School Command, San Diego
- the assumed useful life of the curriculum is 15 years.

The IMI course would be identical to the current CMI version, with the exception that human labor with less complex tools would manage the course rather than a computer. Pedagogically, from the student's viewpoint nothing would be different.

Under the CMI layout, the eight OPSCAN terminettes are deployed in pairs in each of four rooms. These four locations are the students' points of interaction with the computer (figure 2). The proposed IMI scenario would maintain the same layout but replace the computer and the four pairs of OPSCAN terminettes with four testing centers and a central accounting section (figure 3).

The function of the four testing centers would be to grade students' tests as they were completed, refer the students to remedial material, if necessary, and post these procedures to the students' records. Each center would require an automatic test scoring machine and three individuals on duty every class day.

The central accounting section would work either the second or third shift each school day. Its function would be to provide the daily student progess reports required for effective self-paced direction, and to provide those statistical and personnel management services currently being supplied by the CMI system; e.g., test item analyses, student performance data, and school workload information. Requirements for this office would include three clerks and minimal office equipment. Figure 3 also identifies a fourth clerk "floater" who would be required to fill in at the central accounting or test center sections when normal absences occur; e.g., leave.

To transform the CMI costs outlined in the previous section to IMI costs, the following costs must be added:

ONETIME INVESTMENT:

4 test scoring machines	$ 2,000
miscellaneous office equipment	3,000
Total	$ 5,000

ANNUAL OPERATING COSTS:

1 GS-5/step 5	$ 17,000
16 GS-4/step 5	251,000
Total	$268,000 annually

It is anticipated that any computer comparable with a D.E.C. (PDP-11 series) or a VAX (11-750) could manage the RM-A Core curriculum. A typical lease price of such a computer, eight OPSCAN terminettes, and associated modems would be approximately $53,000 per year.

Maintenance and Utilities for School Facilities. Construction costs of facilities were subtracted from current full-service building lease costs in San Diego in order to estimate the costs attributable to maintenance and utilities. The resulting cost factor--$4.70/ft^2/year--reasonably estimates the value of those maintenance services and utilities. The total annual costs incurred in the 28,700 ft^2 RM-A Core CMI area are projected to be $134,000.

Supplies. Currently, the RM-A Core course is using approximately $66,000 worth of supplies per year. This actual cost was used as the annual supply cost projection for this study.

Curriculum Maintenance. After a course is developed and placed in operation, the curriculum must be maintained by the teaching activity. Course maintenance includes changing the curriculum to (1) improve the presentation, (2) adapt it to changes in subject matter, and (3) accommodate changes in student characteristics.

For the past several years, approximately $200,000 per year has been expended in servicing the RM-A school curriculum (Swope and Keeler, 1981, p. 26). Since RM-A Core represents approximately 60 percent of that curriculum, $120,000 was estimated to be the annual curriculum maintenance costs for RM-A Core.

Summary. Total annual operating costs for the CMI RM-A Core course are:

Staff	$ 780,000
Student	5,860,000
Computer Lease	53,000
Facilities (Maintenance and Utilities)	134,000
Supplies	66,000
Curriculum Maintenance	120,000
Total Annual Operating Costs	$7,013,000

Total CMI Costs. Table 1 shows the total investment costs, annual operating costs, and 15 year life-cycle costs for the RM-A Core course in the CMI mode. The life-cycle costs are discounted; appendix B provides a pro forma statement with undiscounted budget costs.

INSTRUCTOR MANAGED INSTRUCTION CONFIGURATION. An IMI approach was hypothesized for the RM-A Core course. Profile information for this course includes:

- self-paced--7.2 weeks in length
- instructor managed
- 2,600 graduates annually, with an average grade of E-2

TABLE 1. RM-A CORE COSTS--CMI

INVESTMENT COSTS--Onetime	
Curriculum Development	$1,188,000
Specialized Programming	20,000
Class Facilities	929,000
Equipment	1,124,000
TOTAL	$3,261,000
OPERATING COSTS--Annual	
Staff	$ 780,000
Student	5,860,000
Computer Lease	53,000
Facilities Maintenance/Utilities	134,000
Supplies	66,000
Curriculum Maintenance	120,000
TOTAL	$7,013,000
15 YEAR LIFE-CYCLE COST*	$59,224,000

*Investment and all operating costs over the expected 15-year life of the course, discounted to present value terms.

Since the computer and terminettes will be costed as if they were leased products, their costs will be included as part of the operating cost category. The total investment cost of the remaining equipment--the sound slide players, video playback units, and teletypewriters--totals $1,124,000. The useful life of these pieces of equipment is assumed to be 15 years.

Summary. Total investment costs for the RM-A Core course in the CMI configuration are:

Curriculum Development	$1,188,000
Specialized Programming	20,000
Class Facilities	929,000
Equipment	1,124,000
Total Investment Costs	$3,261,000

Operating Costs. The major operating costs for RM-A in the CMI mode included those costs incurred for staff, student, computer hardware lease, supplies, maintenance/utilities for the school facilities, and course curriculum maintenance.

Staff Costs. Currently, the teaching of RM-A Core utilizes approximately:

1 - E9
1 - E8
4 - E7's
20 - E6's
8 - E3's

Their costs were estimated using the Navy Life-Cycle Billet Cost Model (Koehler, 1980, p. B-14). This model provides annual costs to the government of maintaining billets of various rates and ratings. Included are the individuals' pay, allowances, and benefits; e.g., retirement, health care, training, housing, subsistence, commissary subsidies, and VA benefits. The estimated total annual cost for the RM-A Core staff totaled $780,000.

Student Costs. Given the data that the student AOB averages 360 over a year, and that the students are predominantly E1's through E3's, the life-cycle billet cost model yields a cost estimate of $5,860,000 per year for students.

Computer Hardware Lease Costs. Since management of the RM-A course is only one of many functions performed by the single Dual Honeywell 6680 computer at Naval Air Technical Training Center, Memphis (and, therefore, very difficult to place a cost on), and since recent trends reveal a clear movement toward the use of minicomputers and distributive processing for geographically dispersed operations such as those encountered in Navy technical training, it was assumed that the RM-A CMI course was managed by an on-site minicomputer. Such an assumption is justified by the fact that the purpose of this report is not a strict cost accounting of the status quo, but rather a comparison of "good" CMI, IMI, and CI strategies for future use.

Curriculum Development Costs. Previous analyses of IPDC data by the Training Analysis and Evaluation Group (Swope and Keeler, 1981, p. 46) revealed that $1,980,000 was expended for labor, material, contracts, and overhead in the development of the entire RM-A curriculum. Since RM-A Core constitutes 60 percent of the total RM-A course length, it was assumed that RM-A Core's development costs were 60 percent of $1,980,000 or $1,188,000.

Many observers expressed the view that the IPDC expended considerably more effort on the "core" segment than it did on the other ("sea" and "shore") segments. To the extent that this is true, the proration scheme used in the preceding paragraph will underestimate the development costs for RM-A Core. However, any such bias was considered inconsequential since it will be incurred proportionally in all three (CMI, IMI, and CI) alternatives. The purpose of this analysis is not a strict cost accounting of the status quo; rather, it is the determination of the relative costs of the three alternatives.

Specialized Programming. For reasons outlined in the Computer Hardware Lease Costs section (p. 15) the RM-A Core CMI course is assumed to be managed with a distributive processing system utilizing a minicomputer. If such a system were utilized in Navy technical training, a substantial onetime computer programming effort would be required to provide the universal, skeletal teaching software package. This effort would be costly, perhaps totaling as much as $260,000, but would only be required onetime for the entire command. The arbitrary assumption was made that, in the foreseeable future, a total of 13 courses would be placed under such a distributive processing system; therefore, $260,000, divided by 13 would yield a $20,000 share which could be allocated as the RM-A Core share of the burden.

In a strict business sense, such a onetime cost as this $260,000 would be considered R&D. However, since government accountants would not likely count it as R&D, it is being considered here as an investment cost. The label is unimportant; the critical fact is that the dollars be counted.

Class Facilities. Actual construction costs for modern, technical school buildings are currently about $36 per square foot. Since RM-A Core training utilizes approximately 28,700 square feet of class space, the new construction costs would be $1,033,000. However, since buildings have a useful life of 25 years and the life-cycle of this study is 15 years, the $1,033,000 must be adjusted to $929,000 for use in this analysis. (Appendix A provides details of this adjustment.)

Major Equipment. The following items of major equipment are currently being utilized in the RM-A Core course:

64	sound slide players
13	video playback units
107	UGC-6 teletypewriters
97	TT-47 teletypewriters
8	OPSCAN terminettes
1	Dual Honeywell computer (Memphis)

SECTION III

COST APPLICATIONS

In this section, the life-cycle costs for the RM-A Core and IC-A courses will be estimated. Each course will be valuated in IMI, CMI, and CI configurations.

The method used was to first estimate the life-cycle costs for the courses as they exist now in the CMI mode. The school where the courses are taught was visited to determine operating requirements, and the Instructional Program Development Center's (IPDC) accounting records were reviewed to determine curriculum development requirements. The estimated CMI costs diverge from reality in the single area of computer costing; the actual courses are managed by a large central computer in Memphis, while the CMI courses in this report are assumed to be managed by local minicomputers.

These CMI costs were then used as a base from which IMI and CI cost estimates could be made. The factors used to transform today's costs (with the CMI strategy) to cost estimates for the same courses with hypothesized strategies were obtained from a variety of sources--research, opinions of various training command personnel, and assumption. In response to the fact that much of this research and many of these opinions and assumptions are very controversial, sensitivity analyses were performed. These analyses assess the extent to which changes in assumptions or input variables will affect the final cost estimates of the alternatives.

RADIOMAN-A (RM-A) CORE COST ANALYSIS

COMPUTER MANAGED INSTRUCTION CONFIGURATION. RM-A Core is currently taught as a CMI course. Profile information includes:

- computer managed--part of CNTECHTRA's centralized system
- self-paced--7.2 weeks in length
- 2,600 graduates annually, predominantly E-1's through E-3's
- media--printed, sound slide, video, and lectures
- location--Service School Command, San Diego
- provides fundamental radio operator training. Graduates of this "core" curriculum immediately attend either the RM-A Shore or RM-A Sea courses to complete their "A" school training
- curriculum was developed in 1976-77 by the IPDC, San Diego
- assumed useful life of the course is 15 years.

Investment Costs. Since R&D costs are not normally incurred in typical technical school programs, investment costs are the first costs encountered chronologically. These costs include those for curriculum development, specialized computer programming, class facilities, and major equipment.

R&D costs are those costs incurred to develop a new capability to the point where it can be operated at some desired level of reliability. These costs are always the earliest in time and can vary from nearly zero to relatively high magnitudes depending on the complexity and innovativeness of the system. Within the context of this study--the comparison of CI and II--no R&D costs are being encountered.

Investment costs are those onetime initial outlays required to introduce the system into the operational inventory. When viewing the training course as a system, class buildings, specialized computer programming, major equipment, and development of the curriculum should be considered investment costs. Investment costs are the second group to be encountered in time and are typically relatively high in magnitude for a relatively short-time period.

Operating costs are those recurring expenditures required to run this system once it is actively producing its product. In the training context, staff and student billet costs, supplies, curriculum updating, facilities maintenance, and lease costs should be classified as operating costs. This category falls latest in time and is moderate to high in magnitude for a relatively long period of time.

All three categories contribute to the total costs of any system and, therefore, must be included in the cost analysis comparing one system with another. For example, when evaluating CI and II alternative strategies of instruction for a certain training program, the analyst would be wrong to state "CI is preferred to II because CI has lower investment costs." In actuality, II may save enough money vis-a-vis CI in the operating category to more than offset the higher investment costs for II. Only an evaluation of the total relevant life-cycle costs will enable the analyst to make any recommendation concerning the relative efficiencies of competing system alternatives.

TABLE 4. RM-A CORE COSTS--CMI, IMI, AND CI

	CMI	IMI	CI
INVESTMENT COSTS--Onetime			
Curriculum Development	$1,188,000	$1,188,000	$ 832,000
Specialized Programming	20,000	0	0
Class Facilities	929,000	929,000	1,115,000
Equipment	1,124,000	1,129,000	1,208,000
TOTAL	$3,261,000	$3,246,000	$3,155,000
OPERATING COSTS--Annual			
Staff	$ 780,000	$1,048,000	$ 936,000
Student	5,860,000	5,860,000	6,446,000
Computer Lease	53,000	0	0
Facilities Maintenance/Utilities	134,000	134,000	162,000
Supplies	66,000	66,000	66,000
Curriculum Maintenance	120,000	120,000	83,000
TOTAL	$7,013,000	$7,228,000	$7,693,000
15 YEAR LIFE-CYCLE COST*	$59,224,000	$60,925,000	$64,545,000

*Investment and all operating costs over the expected 15 year life of the course, discounted to present value terms.

Development Costs. The course development costs were estimated as $1,188,000 for CMI and IMI, and $832,000 for CI. Figure 4 illustrates the impact that CI development costs of $594,000 to $1,188,000 would have on the 15 year life-cycle costs. The results are that the ranking of CI, IMI, and CMI remains unchanged; the changes in CI course development costs were not large enough to overcome the II savings in other cost categories.

Course Length for CI. The length of the CI version of RM-A Core was postulated to be 8.6 weeks, 20 percent longer than the actual II length of 7.2 weeks. Figure 5 illustrates the impact that CI course lengths of 7.2 to 10 weeks would have on the 15 year life-cycle costs estimated in the previous sections.

The results are that as CI becomes shorter, it would eventually perform the task of training the Navy's requirement more efficiently than IMI and CMI. More specifically, if CI could be brought below 8.0 weeks, it would be more cost effective than a 7.2 week IMI course; if it could be brought below 7.7 weeks in length, it would be more cost effective than a 7.2 week CMI course.

Active Duty Personnel. There is a renewed effort in Congress to raise the real military pay; i.e., inflate the costs of the military vis-a-vis other costs. Potential effects of such an action are illustrated in figure 6.

The results show that life-cycle costs rise considerably as military personnel costs increase. This is no surprise when one realizes that the largest single component of total course cost is student compensation. Also, the ranking of the strategies remains unchanged. This is expected since II uses the "people" resource more efficiently, and as personnel costs rise it will remain more efficient than CI. (If the problem were reversed; i.e., personnel costs were declining vis-a-vis other costs, CI would rapidly become more efficient than II.)

Specialized Programming Costs. The specialized computer programming costs for the CMI system were assumed to be about $260,000 for the NAVEDTRACOM; RM-A Core's share of the total was assumed to be $20,000. Since the $260,000 projection and especially the allocation process resulting in the $20,000 estimate were highly speculative, the sensitivity analysis was performed. Figure 7 shows the impact on life-cycle costs if the specialized programming costs were allowed to vary between $10,000 and $100,000.

Results are that even when the specialized programming costs are allowed to rise as high as $100,000, CMI is still the most efficient strategy. In reality, these programming costs would have to be over $1,720,000 before the IMI system would be more efficient than CMI.

Computer Hardware Costs. Although the computer lease cost in this analysis is an accurate estimate for the proposed minicomputer system, the decision maker may desire information on higher priced systems. For example, many analysts claim that the large centralized computer system will become more costly than distributive processing via the minicomputer as time progresses. This sensitivity analysis reveals the effect of increasing CMI computer costs up to four times that which was estimated in the previous analysis.

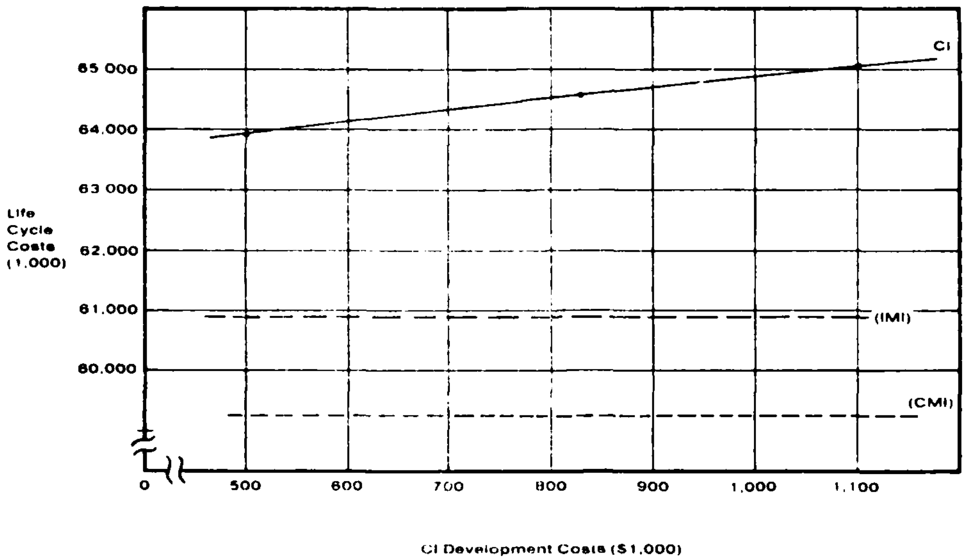


Figure 4. Life-Cycle Costs as a Function of CI Development Costs (RM-A Core)

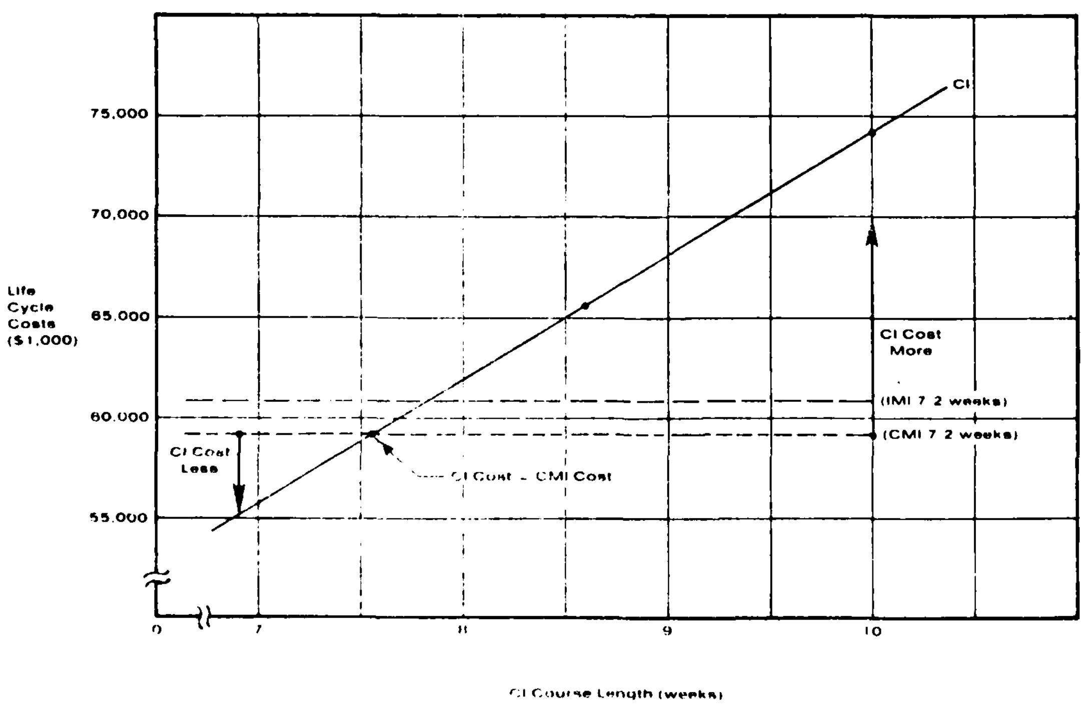


Figure 5. Life Cycle Costs as a Function of CI Course Length (RM-A Core)

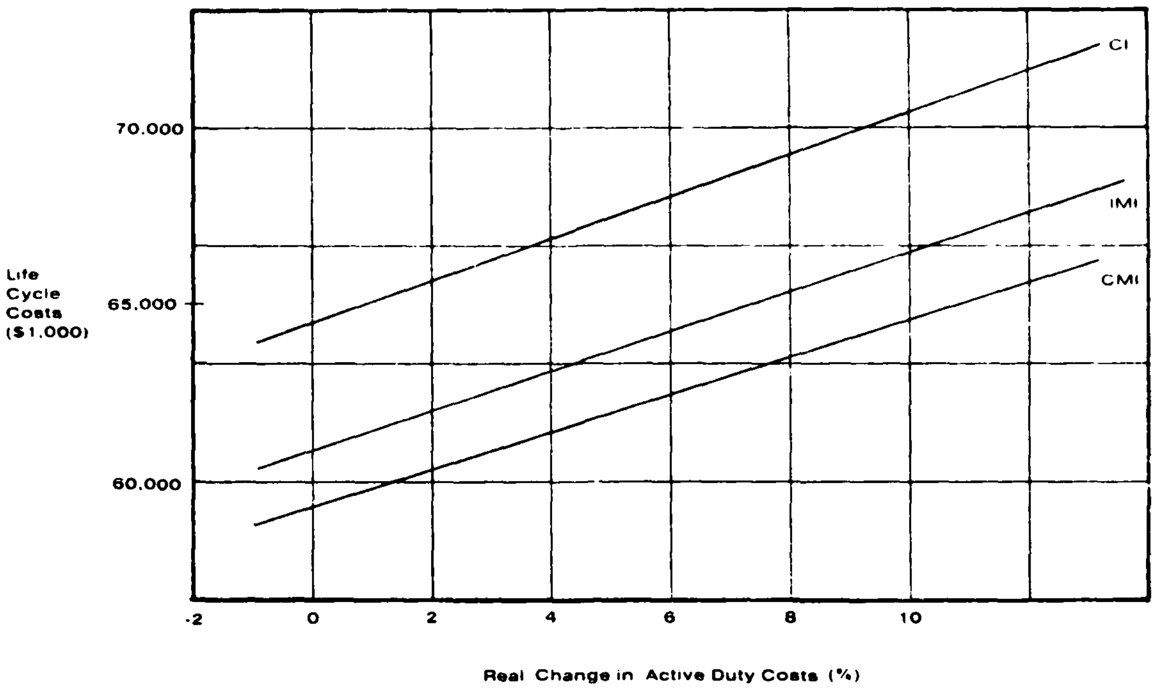


Figure 6. Life-Cycle Costs as a Function of Active Duty Costs (RM-A Core)

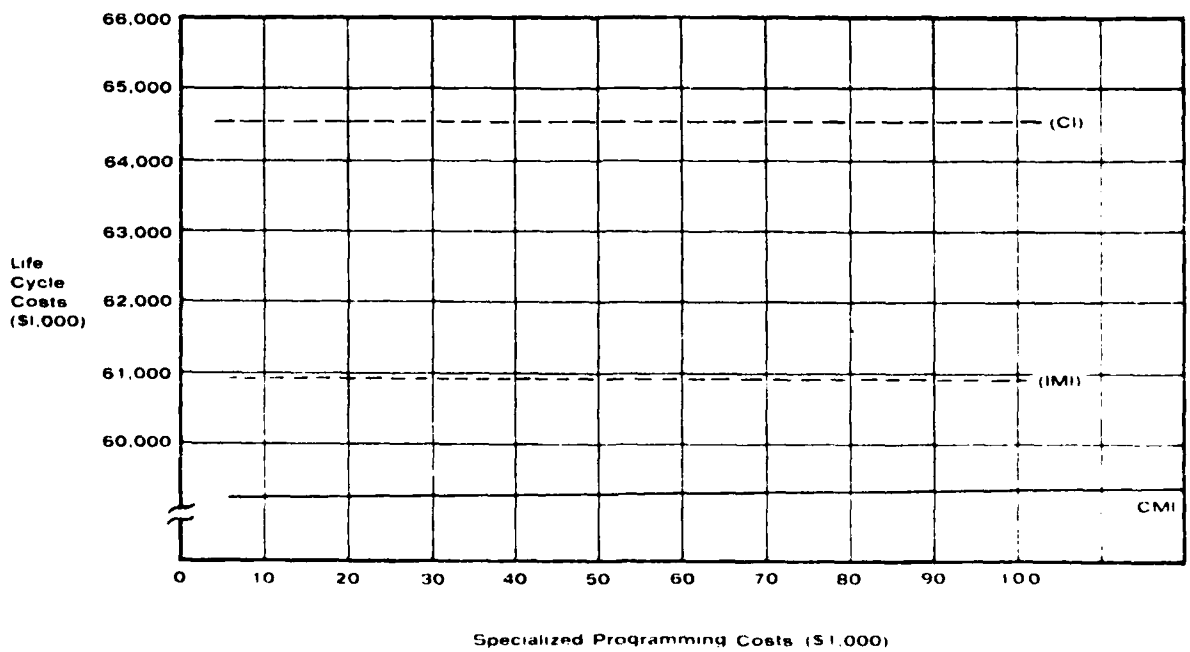


Figure 7. Life-Cycle Costs as a Function of Specialized Programming Costs (RM-A Core)

The results (figure 8) are that these increases in hardware costs are not substantial enough to affect the relative standing of the alternatives.

Number of Graduates. The throughput was allowed to vary to determine how loading would affect the relative efficiencies of CMI, IMI, and CI. The objective of this analysis is to see how costs for courses which are similar in every respect to RM-A Core except throughput would behave under the various alternatives. The model (presented in appendix C) is not accurate enough for managerial decision making involving other courses; it is presented here only to indicate trends.

The results (figure 9) are that as throughput increases, the gap between CMI, II, and CI becomes wider, revealing the increased attractiveness of II for larger courses. The rankings of the alternatives are not affected until the graduate level decreases to between 320 and 440. Only in this low range do the higher equipment and development costs of II become more significant than the higher personnel costs of CI.

INTERIOR COMMUNICATIONS ELECTRICIAN-A (IC-A) COST ANALYSIS

COMPUTER MANAGED INSTRUCTION CONFIGURATION. IC-A is currently taught as a CMI course. Profile information includes:

- computer managed--part of CNTECHTRA's centralized system
- self-paced--6.4 weeks in length
- 900 graduates annually, with an average grade of E-2
- media--printed, sound slide, video, lecture
- location--Service School Command, San Diego
- provides fundamental training on intra-ship communications equipment
- assumed useful life of curriculum is 15 years
- curriculum was developed in 1977-80 by the IPDC, San Diego.

Investment Costs. The onetime investment costs accounted for in the IC-A CMI course include expenditures for curriculum development and equipment, specialized computer programming, and class facilities.

Curriculum Development and Equipment Costs. Previous analysis by TAEG (Swope and Keeler, 1981, page 46) revealed that $3,197,000 has been spent to develop the IC-A course. Included in this amount are the labor, material, and contracted services used in developing the curriculum, plus the equipment; i.e., training devices used in the classroom.

Specialized Programming. As in the RM-A Core case, the CMI is assumed to be operated by a minicomputer. The implementation of such a system would require a onetime programming effort providing universal course management software.

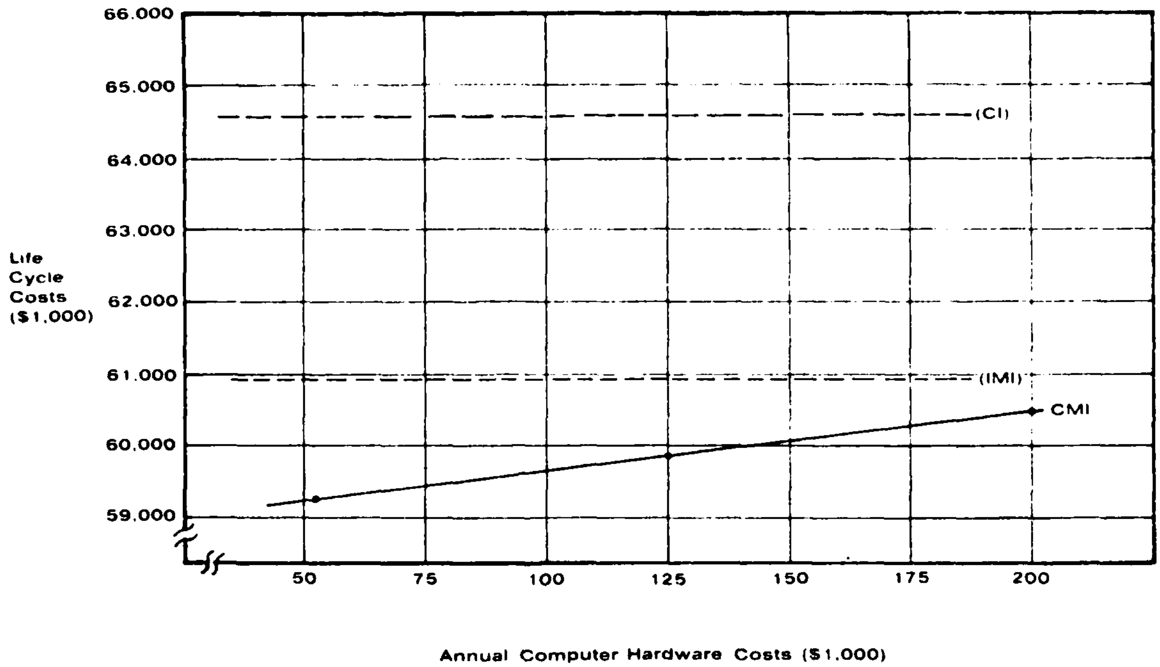


Figure 8. Life-Cycle Costs as a Function of Computer Hardware Costs (RM-A Core)

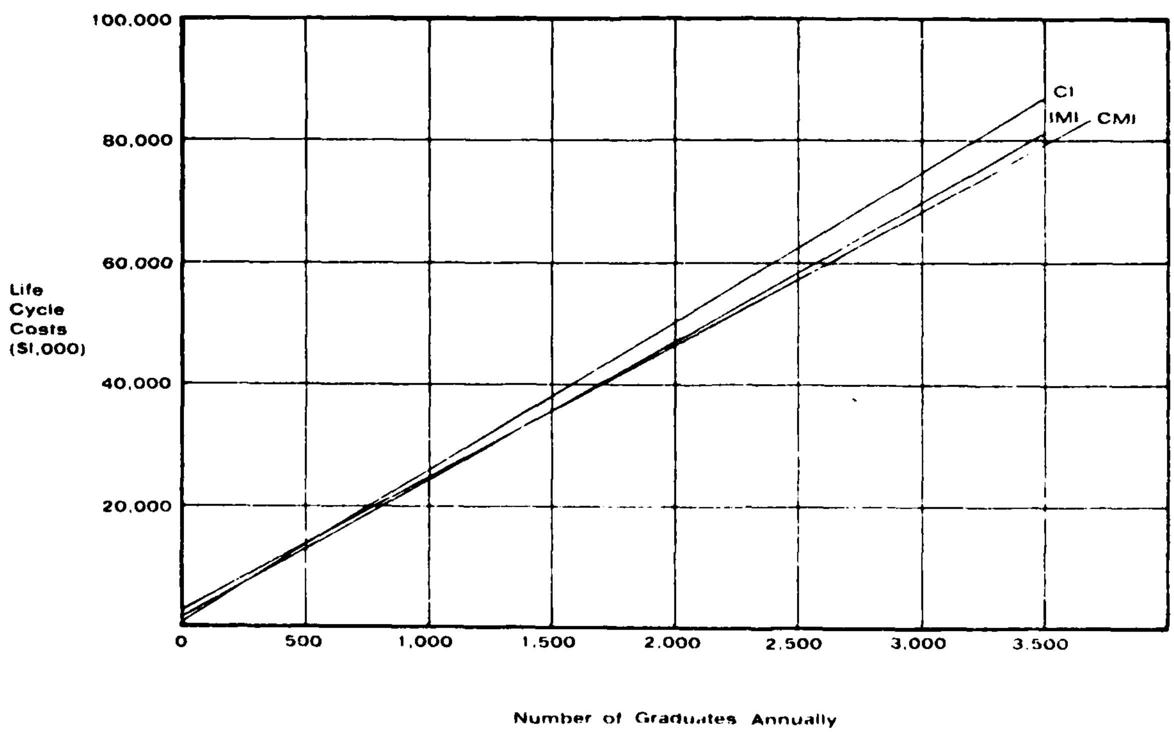


Figure 9. Life-Cycle Costs as a Function of Number of Graduates (RM-A Core)

The total cost of such an effort was estimated to be \$260,000. Assuming that 13 courses were serviced by this software, IC-A's share would be \$20,000.

Class Facilities. Actual construction costs for a new class facility are \$36 per ft^2. Since IC-A uses 10,175 ft^2, new construction costs would total \$336,000. As in the RM-A Core case, this estimate must be adjusted to reconcile the 25 year life of a building with the 15 year life of the course being analyzed. The facilities projection after adjustment is \$329,000.

Summary. Total investment costs for the IC-A course in the CMI configuration are:

Curriculum Development and Equipment	\$3,197,000
Specialized Programming	20,000
Class Facilities	329,000
Total Investment Costs	\$3,546,000

Operating Costs. The major operating costs for IC-A in the CMI mode included those costs for staff, student, computer hardware lease, supplies, maintenance/utilities for the school facilities, and course curriculum maintenance.

Staff Costs. Currently, the teaching of IC-A requires:

1	E-8
1	E-7
11	E-6's
1	E-5

As in the preceding RM-A analysis, life-cycle billet costs were used to evaluate the personnel in order to capture all the costs of maintaining the billets; i.e., pay, allowances, and benefits. The estimated total annual staff cost for IC-A totaled \$338,000.

Student Costs. Given that the student AOB averages 115 over a year, and that students are predominantly E-1's through E-3's, the life-cycle billet cost model yields a cost estimate of \$1,541,000 per year.

Computer Hardware Lease Costs. For the same reasons expressed in the RM-A Core analysis (page 15), the IC-A CMI course is assumed to be managed by a distributive processing system utilizing a minicomputer. The current IC-A CMI configuration requires only four OPSCAN terminettes. These four units (with modems) plus a minicomputer similar to the D.E.C. (PDP-11 series) could be leased for approximately \$32,000 per year.

Maintenance and Utilities for School Facilities. Using the \$4.70/ft^2/year cost factor for maintenance and utilities derived in the RM-A Core analysis (page 17), the costs for IC-A school maintenance and utilities is estimated to be \$48,000 per year.

Supplies. Currently, the IC-A course is using \$24,000 in supplies per year. This actual amount was used to estimate the annual supply costs for this study.

Curriculum Maintenance. After a course is developed and placed in operation, the curriculum must be maintained by the teaching activity. Course maintenance includes changing the curriculum to (1) improve the presentation, (2) adapt it to changes in subject matter, and (3) accommodate changes in student characteristics.

Actual experience in the RM-A course reveals that approximately 10 percent of the course development costs are required each year in curriculum maintenance. In the case of IC-A, it was assumed that curriculum maintenance would be 7 percent of the development costs. The lower rate was assumed because the base on which the RM-A Core percentage was calculated was relatively lower since it did not include training equipment; i.e., the teletypewriters. The IC-A course development costs included class equipment; e.g., anemometers and pit logs.

Seven percent of $3,197,000 yields an annual course maintenance cost of $224,000.

Summary. Total annual operating costs for the CMI IC-A course are:

Staff	$ 338,000
Student	1,541,000
Computer Lease	32,000
Facilities (Maintenance and Utilities)	48,000
Supplies	24,000
Curriculum Maintenance	224,000
Total Annual Operating Costs	$ 2,207,000

Total CMI Costs. Table 5 shows the investment costs, annual operating costs, and 15 year life-cycle costs for the IC-A course in the CMI configuration. The life-cycle costs are discounted; appendix B includes undiscounted budget totals.

INSTRUCTOR MANAGED INSTRUCTION CONFIGURATION. An IMI approach was hypothesized for the IC-A course. Course profile information includes:

- self-paced--6.4 weeks in length
- instructor managed
- 900 graduates annually, with an average grade of E-2
- media--print, sound slide, video, lecture
- location--Service School Command, San Diego
- assumed useful life of curriculum is 15 years.

The IMI course would be identical to the CMI version, with the exception that human labor with less complex tools would manage the course rather than a computer. Pedagogically, from the student's point of view IMI and CMI would be identical.

TABLE 5. IC-A COSTS--CMI

INVESTMENT COSTS--ONETIME	
Curriculum Development and Equipment	$ 3,197,000
Specialized Programming	20,000
Class Facilities	329,000
TOTAL	$ 3,546,000
OPERATING COSTS--Annual	
Staff	$ 338,000
Student	1,541,000
Computer Lease	32,000
Facilities Maintenance and Utilities	48,000
Supplies	24,000
Curriculum Maintenance	224,000
TOTAL	$ 2,207,000
15 Year Life-Cycle Cost*	$21,157,000

*Investment and all operating costs over the expected 15-year life of the course, discounted to present value terms.

In the CMI configuration, four OPSCAN terminettes with computer support are deployed to assimilate and distribute information for course management. The proposed IMI scenario would maintain the same basic plan; the difference would be that each of the terminals would be replaced by laborers with test grading machines, and the computer would be replaced by a central accounting office. Figures 10 and 11 depict the CMI and IMI management systems.

The personnel within the IMI testing centers and central accounting section would be doing what the computer system did in the CMI system--test students, direct remediation, record each student's progress, provide various daily summary reports for instructors, and provide statistical and personnel management services for the staff.

Total requirements for the management team in the IMI IC-A course (figure 11) include 1 GS-5 supervisor, 8 GS-4's, 2 automatic grading machines, and minimal office equipment.

To transform the CMI costs of the previous section to IMI costs, the following costs must be added:

ONETIME INVESTMENT:

2 test scoring machines	$ 1,000
Miscellaneous office equipment	2,000
Total	$ 3,000

ANNUAL OPERATING COSTS:

1 GS-5/step 5	$ 17,000
8 GS-4/step 5	125,000
Total	$142,000 annually

Also, to complete the transition from CMI into IMI costs, the following must be subtracted from the CMI totals:

ONETIME INVESTMENT:

Specialized programming	($20,000)

ANNUAL OPERATING COSTS:

Computer leasing	($32,000)

Summary. Table 6 shows the total investment costs, annual operating costs, and 15 year life-cycle costs for the CMI and IMI instructional strategies for the IC-A course. The life-cycle costs are discounted; appendix B includes a pro forma statement with undiscounted budget totals.

CONVENTIONAL INSTRUCTION CONFIGURATION. As was the case with the RM-A analysis, the most difficult alternative to postulate for IC-A was the CI alternative. Since the real life situation is that IC-A is individualized, any effort to suggest its appearance in a CI configuration is necessarily based upon conjecture by managers and researchers.

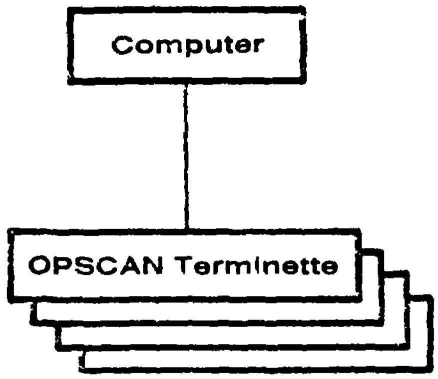


Figure 10. CMI Management System (IC-A)

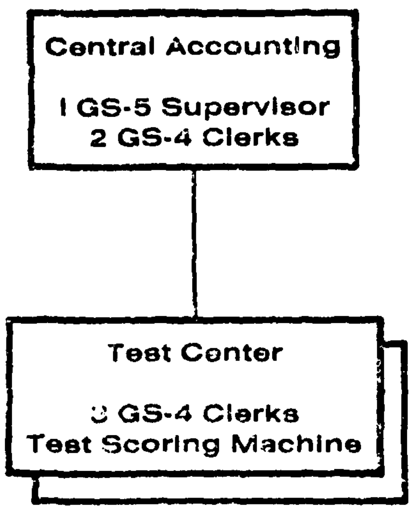


Figure 11. IMI Management System (IC-A)

TABLE 6. IC-A COSTS--CMI AND IMI

INVESTMENT COSTS--ONETIME	CMI	IMI
Curriculum Development and Equipment	$ 3,197,000	$ 3,200,000
Specialized Programming	20,000	0
Class Facilities	329,000	329,000
TOTAL	$ 3,546,000	$ 3,529,000
OPERATING COSTS--Annual		
Staff	$ 338,000	$ 480,000
Student	1,541,000	1,541,000
Computer Lease	32,000	0
Facilities Maintenance and Utilities	48,000	48,000
Supplies	24,000	24,000
Curriculum Maintenance	224,000	224,000
TOTAL	$ 2,207,000	$ 2,317,000
15 Year Life-Cycle Costs*	$21,157,000	$22,018,000

*Investment and all operating costs over the expected 15-year life of the course, discounted to present value terms.

The profile of the CI IC-A course to be analyzed in this section follows:

- group-paced--7.7 weeks long
- 900 graduates annually, predominantly E-1's through E-3's
- media--printed narratives and instructors' oral presentations
- location--Service School Command, San Diego
- assumed useful life of the curriculum is 15 years.

: differences between the CI profile and the preceding individualized profiles : the increased course length, more limited media selection, and the lack (in : CI alternative) of an elaborate course management system. The rationale for ;uming the increased course length and for eliminating the management system the same as it was in the RM-A Core case (see pages 20-23).

The components of the life-cycle costs of the IC-A course in the CI config- ıtion follow:

/estment Costs. These costs include those for curriculum development and ıipment, and facilities.

·riculum Development and Equipment. As demonstrated in the RM-A Core section ıge 23), no conclusive evidence exists which accurately models the relationship :ween CI and II curriculum developmental costs. The most popular initial ;umption to make is that the developmental costs for CI will be about 70 per- ıt of those for II.

The equipment costs will vary proportionately with student AOB. As the ınsition from II to CI occurs, the course will lengthen (assuming a constant ıber of graduates), AOB will rise, and, therefore, equipment costs will increase. this case, AOB is rising by 20 percent; therefore, it is assumed that equip- ıt costs will rise by 20 percent.

The total II costs for curriculum development and equipment were approxi- :ely $3.2 million. Assuming that $2.5 million was for curriculum development l the remaining $700,000 was for equipment, and applying the factors for ınsforming II costs to CI costs outlined in the two preceding paragraphs, the :imate for CI curriculum development and equipment costs becomes $2,590,000.

ıss Facilities. Class facility requirements are directly related to AOB. ıce CI will require an AOB 20 percent greater than that experienced under II, ;ts for facilities are estimated to rise by 20 percent above those projected · the II programs. The CI projection is $394,000.

ımary. Total investment costs for the IC-A course in the CI configuration ::

Curriculum Development and Equipment	$2,590,000
Class Facilities	394,000
Total	$2,984,000

Operating Costs. Operating costs for IC-A in the CI configuration include those for staff, students, supplies, maintenance and utilities for the school facilities, and curriculum maintenance.

Staff Costs. The student-instructor ratio was assumed not to vary with instructional strategy. Therefore, the 20 percent increase in student AOB projected with the CI alternatives would cause a 20 percent increase in CI staff costs vis-a-vis CMI staff costs. The resulting cost estimate for staff requirements is $407,000 annually.

Student Costs. The 20 percent increase in student AOB experienced in transforming II to CI will translate into a 20 percent increase in student costs. The student cost projection for the CI alternative is, therefore, $1,849,000.

Supplies. Supplies for the CI configuration were assumed to be the same as those for the CMI course, or $24,000 per year.

Maintenance and Utilities for School Facilities. The $4.70/ft^2 cost factor for maintenance and utilities yields an annual estimate of $57,000.

Curriculum Maintenance. As in the RM-A Core case (page 25), curriculum maintenance was assumed to be 10 percent of the initial course development cost. Using that portion of the CI IC-A curriculum development and equipment costs assumed to be a result of course development efforts--$2.5 million (page 38)--the annual curriculum maintenance projection becomes $250,000.

Summary. Total annual operating costs for IC-A in the CI mode are:

Staff	$ 407,000
Student	1,849,000
Supplies	24,000
Facilities (Maintenance and Utilities)	57,000
Curriculum Maintenance	250,000
Total Annual Operating Costs	$2,587,000

Summary. Table 7 shows the onetime investment costs, annual operating costs, and total 15 year life-cycle costs for the IC-A course with CMI, IMI, and CI strategies. Life-cycle costs are discounted; appendix B includes a pro forma statement with undiscounted budget dollars.

SENSITIVITY ANALYSIS. In the preceding analysis of the IC-A course, estimates and assumptions were made which might not prove true in reality. To evaluate the potential impacts of these possible errors, a sensitivity analysis was performed. The IC-A 15 year life-cycle costs were recalculated for scenarios where:

- curriculum development costs for the hypothesized CI option ranged from $1.8 million to $3.2 million. (In the preceding analysis, it was assumed to be $2.5 million excluding equipment.)

- course length for the CI alternative ranged from 100 percent to 135 percent of the II course length (or 6.4 to 8.6 weeks).

Since there exists a time value of money, costs incurred in outyears be discounted to present dollars when comparing costs from different s. DOD instructions stipulate that a 10 percent discount factor will be . Illustrative examples of the discounting process follow.

ᴾLE 1

Two computers are available for lease to manage our CMI course. Firm "X" ges an initial fee of $10,000 and a $1,200 annual leasing fee. Firm "Y" ges only a flat lease fee of $3,500 per year. The "economic life," or expected period of rental, is 5 years. Which should be purchased?

TION 1

Table A-1 depicts the value of $1 now (0), and in outyears 1 through 5 n the discount rate is 10 percent.

TABLE A-1. PRESENT VALUE OF $1 DUE IN YEAR N

Year (N)	Discount Factor (10%)
0	1
1	.954
2	.867
3	.788
4	.717
5	.652

Computer "X" has a cash flow which can be depicted by:

Economic Life = 5 Years

	0	1	2	3	4	5
Flow	(10K)	(1.2K)	(1.2K)	(1.2K)	(1.2K)	(1.2K)

The present value of these costs equals:

$PV_x = 10K(1) + 1.2K(.954) + 1.2K(.867) + 1.2K(.788) + 1.2K(.717) + 1.2K(.652)$

$PV_x = \$14.77K$

APPENDIX A

TIME VALUE OF MONEY

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The impact of such managerial decisions is particularly evident with curriculum development costs. Decisions made in this area determine the levels of all the remaining life-cycle costs. A few dollars effectively spent here can easily be paid back many times over in a very short time. Curriculum development costs are typically much less than 10 percent of the total life-cycle costs, yet are most important since they ultimately determine the absolute level of all the other costs.

The relative advantages/disadvantages of instructional strategies (II vs. CI) and the subsequent evaluation of the differences in training effectiveness (i.e., a cost-benefit analysis) were not addressed in this study. The lack of any firm data measuring the relative qualitative differences in the strategies prevents any such study at this time. As such information becomes available, it must be incorporated into any economic/training effectiveness comparison of the strategies.

RECOMMENDATIONS

It is recommended that:

- formal economic analyses be part of every major course development (where major courses are those with annual AOB's greater than 75). Evaluations should address all feasible instructional development and delivery alternatives. Swope and Green (1978) and OMB Circular A-76 are excellent guides for such analyses. This present study, Corey (1980), and Swope and Green (1978) provide illustrative examples of economic analyses applied to training courses.

- major course developments should be considered prime candidates for II. Any decision to develop a major course in the CI mode should be reviewed at the CNET level.

Such formal economic considerations are essential. As demonstrated in this report, courses are major investment projects with life-cycle costs of many millions of dollars. RM-A Core, for example, has a discounted project cost of over \$60 million, or in terms of inflated budget dollars, approximately \$200 million. These projects are of sufficient size to warrant economic analyses and reviews.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

When given the choice of several instructional alternatives which have the capabilities of training students to a given level, the decision on which alternative to adopt should be based on least cost criteria. The selection of the least costly alternative is the only way to assure that the Navy produces the most defense possible given its budgetary constraints.

The cost comparison performed must include total relevant resource costs incurred throughout the life of the course. Any decision criteria based on only part of the life-cycle costs will almost certainly lead to inefficient results (Corey, 1980).

The cost-effectiveness analyses performed in this study reveal that the RM-A Core and IC-A courses can be most efficiently taught with individualized curricula, and that these curricula can be more efficiently managed by a computer rather than by human effort.

After reviewing the sensitivity analyses performed in this study, several additional conclusions can be made. These are:

- The most expensive resource used in training is the student population. Over the life of most courses, their cost will be greater than all the other resource costs combined. For example, in the current RM-A course now being taught, $75 per day per student is required for pay and benefits. If the course were shortened by one day (and the graduation rate remained at the current 2,600 annual level), $195,000 per year would be freed for other uses. Or in real terms, for each day's reduction in course length, 10 man-years of Radioman Seaman effort would be freed for operational use.

- Developments in the computer industry are making CMI increasingly attractive when compared to IMI. A powerful minicomputer can now be leased for less annual cost than a GS-5 clerk. When the task involves rapid manipulation of data and daily production of reports, the favorable benefit-cost ratio of the computer vis-a-vis the clerk becomes apparent.

- Certain sensitive cost elements; e.g., curriculum development, computer acquisitions, and audio-visual equipment purchases, pale in significance when compared with students' time. Consequently, administrative edicts hampering the purchase of these managerially sensitive items in order to save costs could force costs up in nonsensitive areas until diseconomies result. For example, if a "cost saving" moratorium on computer leasing would have been in place when IC-A was developed, IMI would have been the second best choice. Even though such a move would have saved $32,000 per year in computer costs, it would have wasted $142,000 in extra personnel costs, yielding a net loss of $110,000 per year.

distributive processing as time progresses. This sensitivity analysis reveals the effect of increasing those computer costs up to four times that which was estimated in the previous analysis.

The results (figure 16) are that these increases in hardware costs are not substantial enough to affect the relative standing of the alternatives.

Number of Graduates. The throughput was allowed to vary to determine how loading would affect the relative efficiencies of CMI, IMI, and CI. The objective of this analysis is to see how costs for courses which are similar in every respect to IC-A (except throughput) would behave under the various alternatives. The model (presented in appendix C) is not accurate enough for managerial decision making involving other courses; it is presented here only to indicate trends.

The results (figure 17) are that as throughput increases, the gap between CMI, II, and CI becomes wider, revealing the increased attractiveness of II for larger courses. The ranking of the alternatives is not affected until the graduate level decreases to between 185 and 150. Only in this low range do the higher equipment and development costs of II become more significant than the higher personnel costs of CI.

COST-BENEFITS

The preceding analyses of RM-A Core and IC-A were cost-effectiveness studies. That is, they were comparisons of several alternatives whose products (or benefits) were assumed to be equal. Without any evidence of differing benefits among the individualized and conventional programs, the more complex cost-benefit studies were impossible.

When performance data becomes available, it could significantly affect the decisions concerning strategy choice. Proponents of II suggest that students have a better attitude toward individualized programs and that this improved attitude translates into a better graduate. They also suggest that the quality of training would be enhanced through special remediation materials which can be offered on the basis of information gained from II's frequent diagnostic testing.

Proponents of CI suggest that instructors have a better attitude toward conventional programs and that this translates into better trained graduates. They argue also that benefits are gained from CI's group-paced environment where the young students learn to act as a member of a military unit (the class). They contend that this regimentation in the school will make the graduates better members of the operational military units to which they are bound.

However, cost-benefit analyses of such qualitative factors as those suggested above must await further research. Empirical evidence is needed to prove whether such CI and II characteristics really do exist and to what degree they exist.

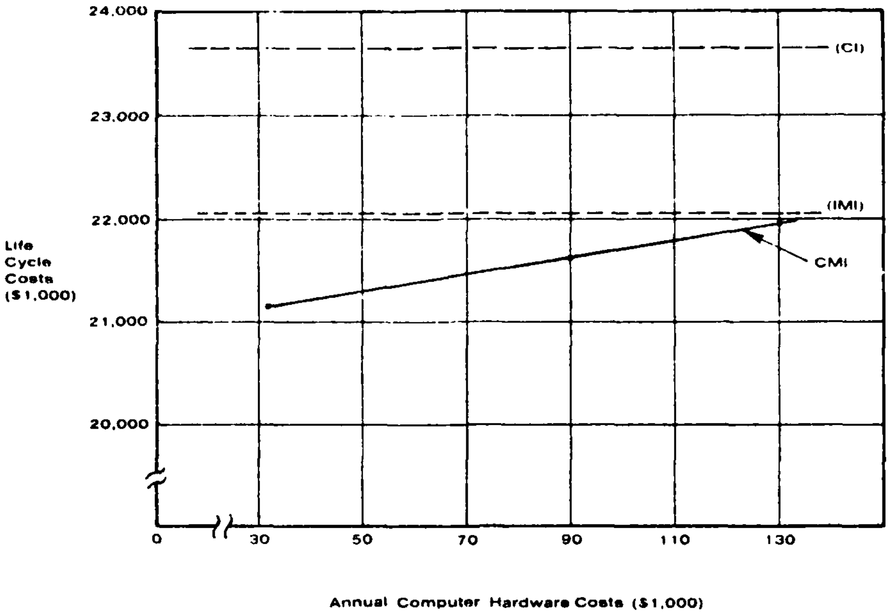

Figure 16. Life-Cycle Costs as a Function of Computer Hardware Costs (IC-A)

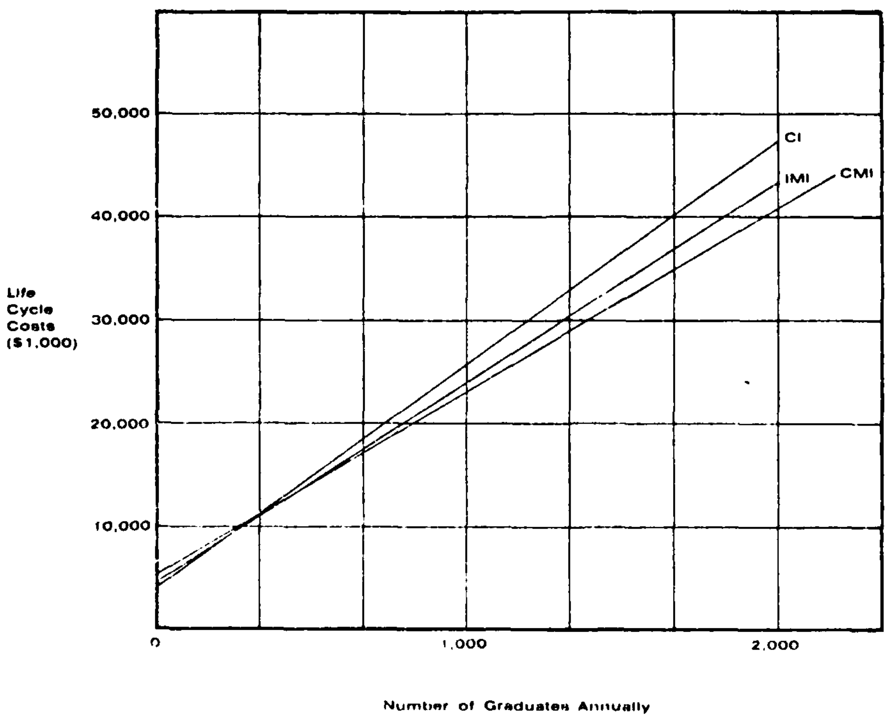

Figure 17. Life-Cycle Costs as a Function of Number of Graduates (IC-A)

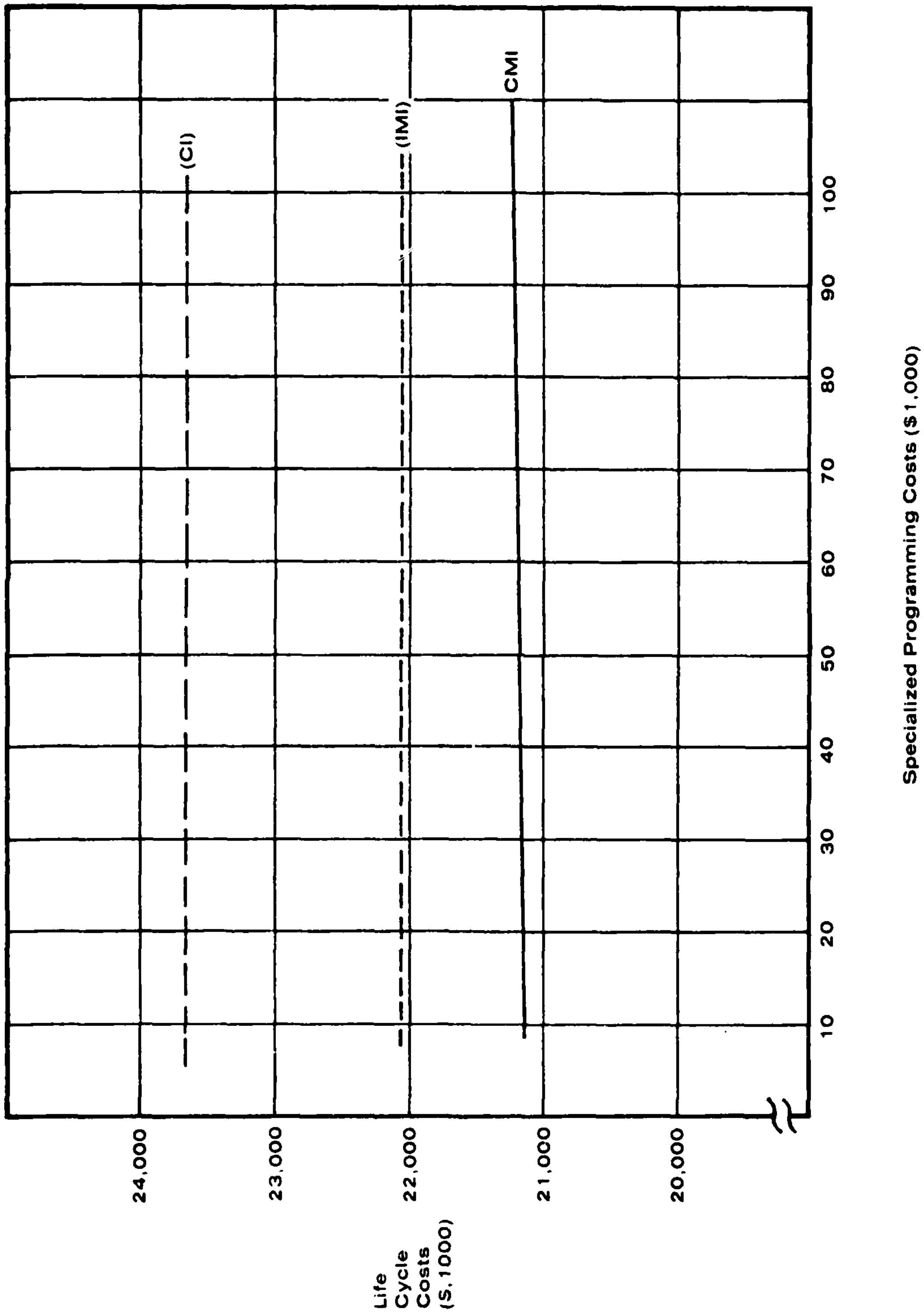

Figure 15. Life-Cycle Costs as a Specialized Programming Costs (IC-A)

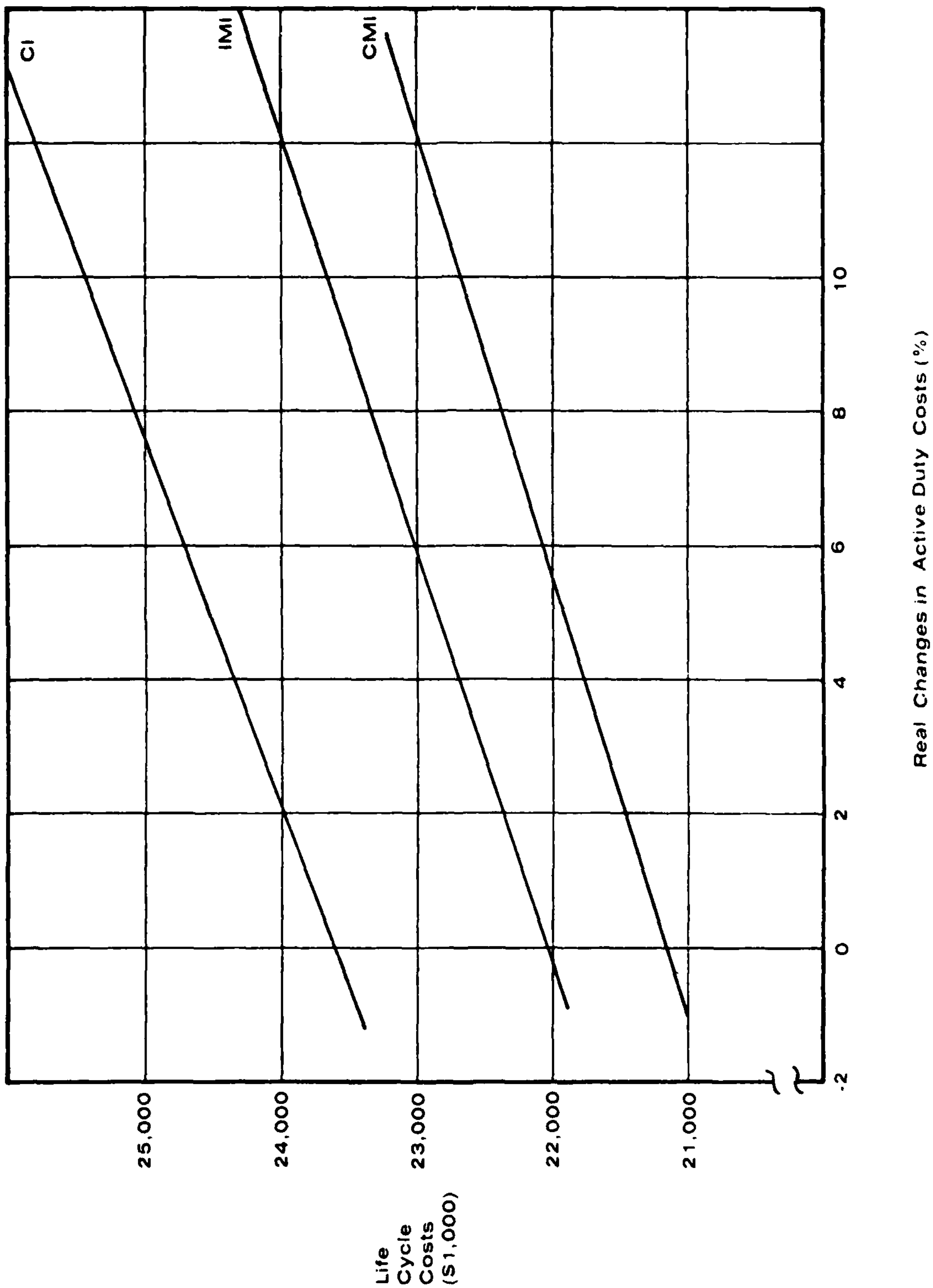

Figure 14. Life-Cycle Costs as a Function of Active Duty Costs (IC-A)

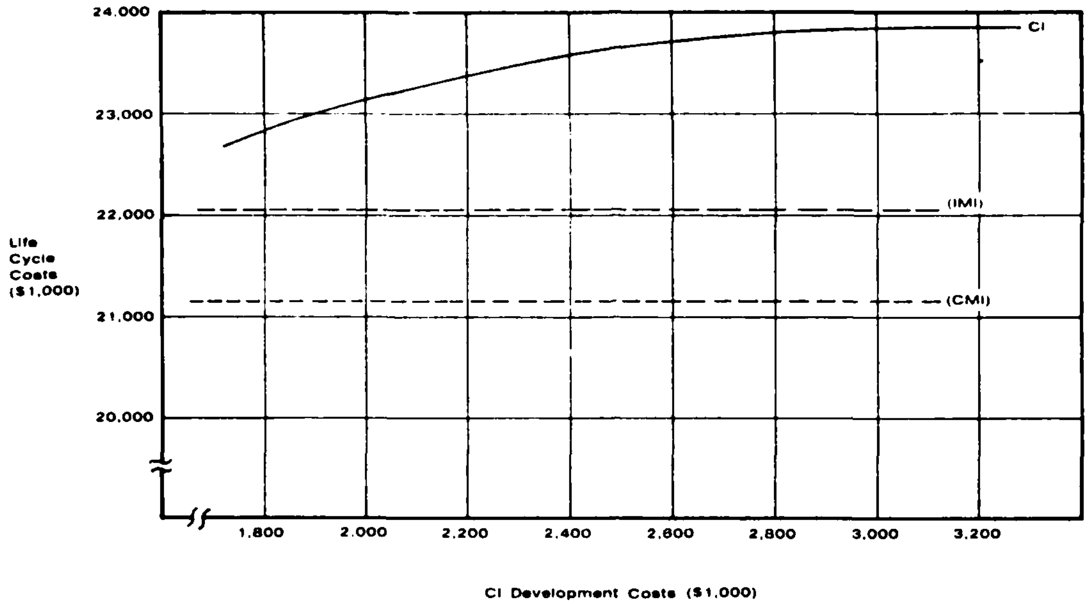

Figure 12. Life-Cycle Costs as a Function of CI Development Costs (IC-A)

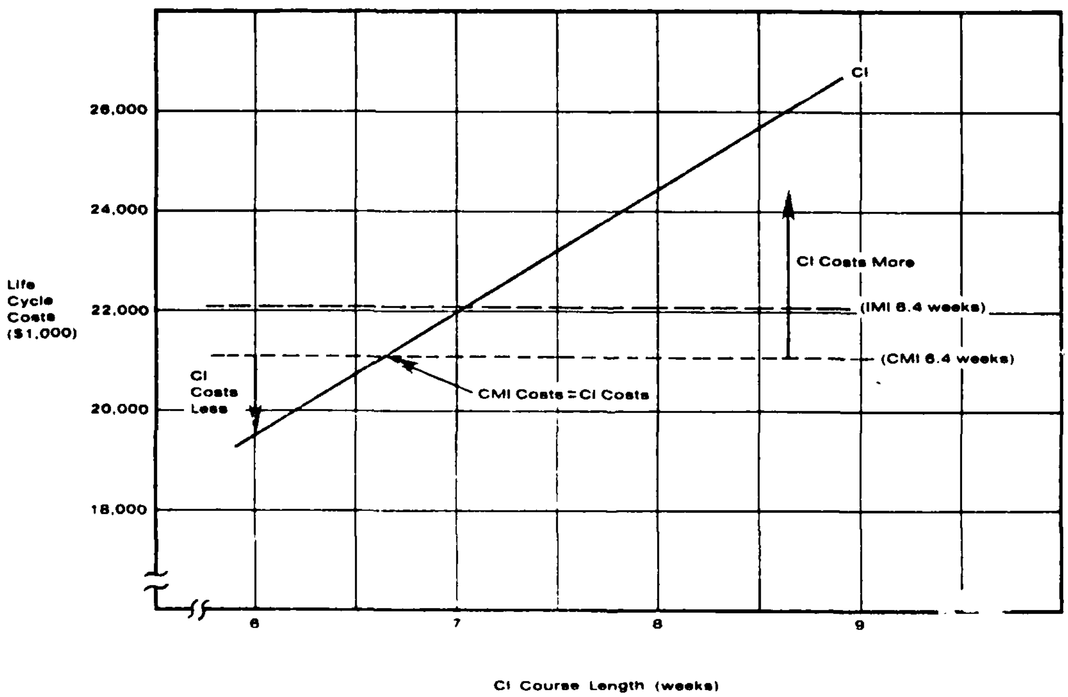

Figure 13. Life-Cycle Costs as a Function of CI Course Length (IC-A)

- costs of active duty personnel rose from 0 percent to 10 percent more quickly than other costs.

- the specialized computer programming for the CMI system would cost 50 percent to 500 percent of the $20,000 estimated in the preceding section (or would equal between $10,000 and $100,000).

- computer hardware costs ranged from $30,000 to $120,000 annually.

- the number of graduates in all three alternatives varied from 0 to 2,300 per year.

Curriculum Development Costs. The CI curriculum development costs (excluding training equipment) were estimated to be $2.5 million. Figure 12 illustrates the impact that CI development costs of $1.8 million to $3.2 million would have on the 15 year life-cycle costs.

The results are that the ranking of the CI, IMI, and CMI strategies remains unchanged. The changes in CI course development costs were not great enough to overcome the II savings in other cost categories.

Course Length of CI. Figure 13 illustrates the impact on life-cycle costs that a CI course length between 6.4 and 8.6 weeks would have. The results are that as CI becomes shorter, it would eventually perform the task of training the Navy's requirement more efficiently than IMI or CMI. The cross-over point for IMI is a course length of 7.0 weeks, while the cross-over point for CMI is 6.6 weeks.

Active Duty Personnel. In response to the current efforts to increase the real military compensation; i.e., inflate the military pay at a faster rate than other costs, the courses were analyzed with 0 percent to 10 percent higher real active duty costs.

The results (figure 14) show that life-cycle costs rise considerably as personnel costs rise. This is expected since instruction is extremely labor intensive. Also, the relative rankings of CMI, IMI, and CI do not change. This is anticipated since at the 0 percent starting point they were already ranked in terms of how efficiently labor was utilized. (If the problem were reversed; i.e., personnel costs were falling, CI would rapidly become the more efficient option.)

Specialized Programming Costs. Using the same rationale as in the RM-A Core case (page 27), the specialized programming costs were allowed to vary between $10,000 and $100,000. Figure 15 illustrates the impact of this variation. As expected, CMI costs increase. However, the impact is minimal and is insufficient to affect the ranking of the three strategies. In reality, the specialized programming expenditures would have to reach $881,000 before IMI would become more efficient than CMI.

Computer Hardware Costs. Although the computer cost in this analysis is an accurate estimate for the proposed minicomputer system, the decision maker may desire information on higher priced systems. For example, many analysts claim that the large centralized computer system will become more expensive than

TABLE 7. IC-A COSTS--CMI, IMI, AND CI

	CMI	IMI	CI
INVESTMENT COSTS--Onetime			
Curriculum Development and Equipment	$ 3,197,000	$ 3,200,000	$ 2,590,000
Specialized Programming	20,000	0	0
Class Facilities	329,000	329,000	394,000
TOTAL	$ 3,546,000	$ 3,529,000	$ 2,984,000
OPERATING COSTS--Annual			
Staff	$ 338,000	$ 480,000	$ 407,000
Student	1,541,000	1,541,000	1,849,000
Computer Lease	32,000	0	0
Facilities Maintenance and Utilities	48,000	48,000	57,000
Supplies	24,000	24,000	24,000
Curriculum Maintenance	224,000	224,000	250,000
TOTAL	$ 2,207,000	$2,317,000	$ 2,587,000
15 Year Life-Cycle Cost*	$21,157,000	$22,018,000	$23,628,000

*Investment and all operating costs over the expected 15 year life of the course, discounted to present value terms.

Computer "Y" has a cash flow which can be depicted by:

Economic Life = 5 Years

	0	1	2	3	4	5
Cash Flow	0	(3.5K)	(3.5K)	(3.5K)	(3.5K)	(3.5K)

The present value of these costs equals:

$$PV_y = 3.5K(.954) + 3.5K(.867) + 3.5K(.788) + 3.5K(.717) + 3.5K(.652)$$

$$PV_y = \$13.92K$$

The "Y" computer is least costly in life cycle terms.

EXAMPLE 2

A third option arises for comparison with the two above. The command learns that it can purchase a computer for $60,000 which has a useful life of 12 years. Even though the economic life of the project is only 5 years, management feels that it could purchase the computer for $60,000 and salvage it for 7/12th of the purchase price, or $35,000 at the end of the 5 year period.

SOLUTION 2

Computer "Z" has a cash flow which can be depicted by:

Economic Life = 5 Years

	0	1	2	3	4	5
Cash Flow	(60K)	0	0	0	0	35K

The present value is:

$$PV_z = 60K(1) - 35K(.652)$$

$$PV_z = \$21K$$

Computer "Z" is more costly than "X" and "Y."

Cost elements with lives longer than the economic life of the project being analyzed; e.g., computer "Z" or buildings in the course alternatives studied in this report, can be counted by estimating the residual value of the asset in the final year of the economic life of the project, and discounting that value by the appropriate factor.

APPENDIX B

FINANCIAL PRO FORMA STATEMENTS

PRO FORMA STATEMENTS
($1,000)

The following statements illustrate the divergence between discounted, constant, and inflated dollars. Row 1 gives the discounted values used in this report. Row 2 shows the scenario costs when constant FY81 dollars are used. Rows 3 and 4 show the future budget costs in current year dollars; two different assumptions are made concerning future inflation rates.

I. RM-A CORE (CMI)

	YEAR																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
Costs (Time discounted to 1981 present value terms)	3,261	6,690	6,080	5,526	4,921	4,572	4,152	3,773	3,429	3,121	2,840	2,581	2,342	2,132	1,935	1,760	59,224
Costs (1981 dollars)	3,261	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013	108,456
Costs (inflated dollars-constant 8% inflation rate)	3,261	7,574	8,205	8,836	9,538	10,309	11,080	11,992	12,974	13,955	15,148	16,340	17,672	19,075	20,618	22,231	208,803
Costs (inflated dollars-8% for years 1-5, and 5% for years 6-15)	3,261	7,574	8,205	8,836	9,538	10,309	10,800	11,361	11,922	12,553	13,184	13,815	14,516	15,218	15,989	16,761	167,813

II. RM-A CORE (IMI)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
Costs (Time discounted to 1981 present value terms)	3,246	6,895	6,267	5,696	5,182	4,713	4,279	3,889	3,534	3,216	2,927	2,660	2,414	2,197	1,995	1,814	60,925
Costs (1981 dollars)	3,246	7,228	7,228	7,228	7,228	7,228	7,228	7,228	7,228	7,228	7,228	7,228	7,228	7,228	7,228	7,228	111,666
Costs (inflated dollars-constant 8% inflation rate)	3,246	7,806	8,457	9,107	9,830	10,625	11,420	12,360	13,372	14,384	15,612	16,841	18,215	19,660	21,250	22,913	215,148
Costs (inflated dollars-8% for years 1-5, and 5% for years 6-15)	3,246	7,806	8,457	9,107	9,830	10,625	11,131	11,709	12,288	12,938	13,589	14,239	14,962	15,685	16,480	17,275	189,367

PRO FORMA STATEMENTS (continued)
($1,000)

III. RM-A CORE (CI)

	YEAR 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
Costs (Time discounted to 1981 present value terms)	3,155	7,339	6,670	6,062	5,516	5,016	4,554	4,139	3,762	3,423	3,116	2,831	2,569	2,339	2,123	1,931	64,545
Costs (1981 dollars)	3,155	7,693	7,693	7,693	7,693	7,693	7,693	7,693	7,693	7,693	7,693	7,693	7,693	7,693	7,693	7,693	118,550
Costs (inflated dollars-constant 8. inflation rate)	3,155	8,308	9,001	9,693	10,462	11,308	12,155	13,155	14,232	15,309	16,617	17,925	19,386	20,925	22,617	24,387	228,635
Costs (inflated dollars-8. for years 1-5, and 5. for years 6-15)	3,155	8,308	9,001	9,693	10,462	11,308	11,847	12,463	13,078	13,770	14,423	15,155	15,925	16,694	17,540	18,386	201,208

IV. IC-A (CMI)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
Costs (Time discounted to 1981 present value terms)	3,546	2,105	1,913	1,739	1,582	1,439	1,306	1,187	1,079	982	894	812	737	671	609	554	21,157
Costs (1981 dollars)	3,546	2,207	2,207	2,207	2,207	2,207	2,207	2,207	2,207	2,207	2,207	2,207	2,207	2,207	2,207	2,207	36,651
Costs (inflated dollars-constant 8. inflation rate)	3,546	2,238	2,582	2,781	3,002	3,244	3,487	3,774	4,083	4,392	4,767	5,142	5,562	6,003	6,489	6,996	64,088
Costs (inflated dollars-8. for years 1-5 and 5. for years 6-15)	3,546	2,238	2,582	2,781	3,002	3,244	3,399	3,575	3,716	3,951	4,149	4,348	4,568	4,789	5,032	5,275	60,195

PRO FORMA STATEMENTS (continued)
($1,000)

V. IC-A (IMI)

	YEAR																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
Costs (Time discounted to 1981 present value terms)	3,529	2,210	2,008	1,826	1,661	1,511	1,372	1,247	1,133	1,031	938	853	773	704	639	582	22,018
Costs (1981 dollars)	3,529	2,317	2,317	2,317	2,317	2,317	2,317	2,317	2,317	2,317	2,317	2,317	2,317	2,317	2,317	2,317	38,284
Costs (inflated dollars-constant 8% inflation rate)	3,529	2,502	2,711	2,919	3,151	3,406	3,661	3,962	4,286	4,611	5,005	5,399	5,839	6,302	6,812	7,345	71,440
Costs (inflated dollars-8% for years 1-5, and 5% for years 6-15)	3,529	2,502	2,711	2,919	3,151	3,406	3,568	3,754	3,939	4,147	4,356	4,564	4,796	5,078	5,283	5,538	63,101

VI. IC-A (CI)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
Costs (Time discounted to 1981 present value terms)	2,984	2,468	2,243	2,038	1,855	1,687	1,532	1,392	1,265	1,151	1,048	952	864	786	714	649	23,628
Costs (1981 dollars)	2,984	2,587	2,587	2,587	2,587	2,587	2,587	2,587	2,587	2,587	2,587	2,587	2,587	2,587	2,587	2,587	41,789
Costs (inflated dollars-8% for years 1-5, and 5% for years 6-15)	2,984	2,794	3,027	3,260	3,518	3,803	4,087	4,424	4,786	5,148	5,588	6,028	6,519	7,037	7,606	8,201	78,837
Costs (inflated dollars-8% for years 1-5, and 5% for years 6-15)	2,984	2,794	3,027	3,260	3,518	3,803	3,984	4,191	4,398	4,631	4,866	5,096	5,355	5,614	5,989	6,183	69,629

APPENDIX C

EFFECT OF NUMBER OF GRADUATES UPON LIFE-CYCLE COSTS

In an effort to gather evidence on how costs might appear for other courses with different throughputs, the RM-A Core and IC-A course scenarios developed in the main body of this study were put through a sensitivity analysis where throughput was allowed to vary. The results are summarized in figures 9 and 17 (pages 31 and 45).

Several assumptions were made to calculate the functions on which the sensitivity analysis was based. These assumptions were:

- Curriculum development, specialized programming, computer lease, and curriculum maintenance costs were fixed; they did not vary with the number of graduates.
- Class facilities, equipment, staff, student, facilities maintenance and utilities, and supplies varied directly and linearly with throughput. For example, if throughput was decreased to the extreme point where the students were attending for only a part of the year, it was assumed that instructors could teach during that period and then be productively employed elsewhere during the school's dead time.
- For all linear relationships, the cost rate (or slope) was assumed to be the actual cost per graduate for the major scenarios presented in this study.

Tables C-1 and C-2 present the fixed costs and the costs that vary with student throughput. Together they yield the following life-cycle cost estimating equations:

RM-A Core Life-Cycle Costs (CMI) = 2,588,000 + (21,770 x graduates)
RM-A Core Life-Cycle Costs (IMI) = 2,045,000 + (22,570 x graduates)
RM-A Core Life-Cycle Costs (CI) = 1,494,000 + (24,270 x graduates)

IC-A Life-Cycle Costs (CMI) = 5,608,000 + (17,680 x graduates)
IC-A Life-Cycle Costs (IMI) = 5,316,000 + (18,880 x graduates)
IC-A Life-Cycle Costs (CI) = 4,979,000 + (21,100 x graduates)

TABLE C-1. RM-A COSTING--VARYING THROUGHPUT ($1,000)

	CMI	IMI	CI
INVESTMENT			
Curriculum Development	$1,188	$1,088	$ 832
Specialized Programming	20	0	0
Class Facilities	.36/grad	.36/grad	.43/grad
Equipment	.43/grad	.43/grad	.46/grad
OPERATING COSTS			
Staff	.30/grad	.40/grad	.36/grad
Student	2.25/grad	2.25/grad	2.48/grad
Computer Lease	32	0	0
Facilities Maintenance Utilities	.05/grad	.05/grad	.06/grad
Supplies	.03/grad	.03/grad	.03/grad
Curriculum Maintenance	120	120	83

TABLE C-2. IC-A COSTING--VARYING THROUGHPUT ($1,000)

	CMI	IMI	CI
NVESTMENT			
Curriculum Development	$3,546	$3,529	$2,984
Specialized Programming	20	0	0
Class Facilities	.37/grad	.37/grad	.44/grad
PERATING COSTS			
Staff	.38/grad	.53/grad	.45/grad
Student	1.71/grad	1.71/grad	2.05/grad
Computer Lease	32	0	0
Facilities Maintenance and Utilities	.05/grad	.05/grad	.06/grad
Supplies	.03/grad	.03/grad	.03/grad
Curriculum Maintenance	224	224	250

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